FEBRUARY 21, 1957
EVERY OTHER THURSDAY

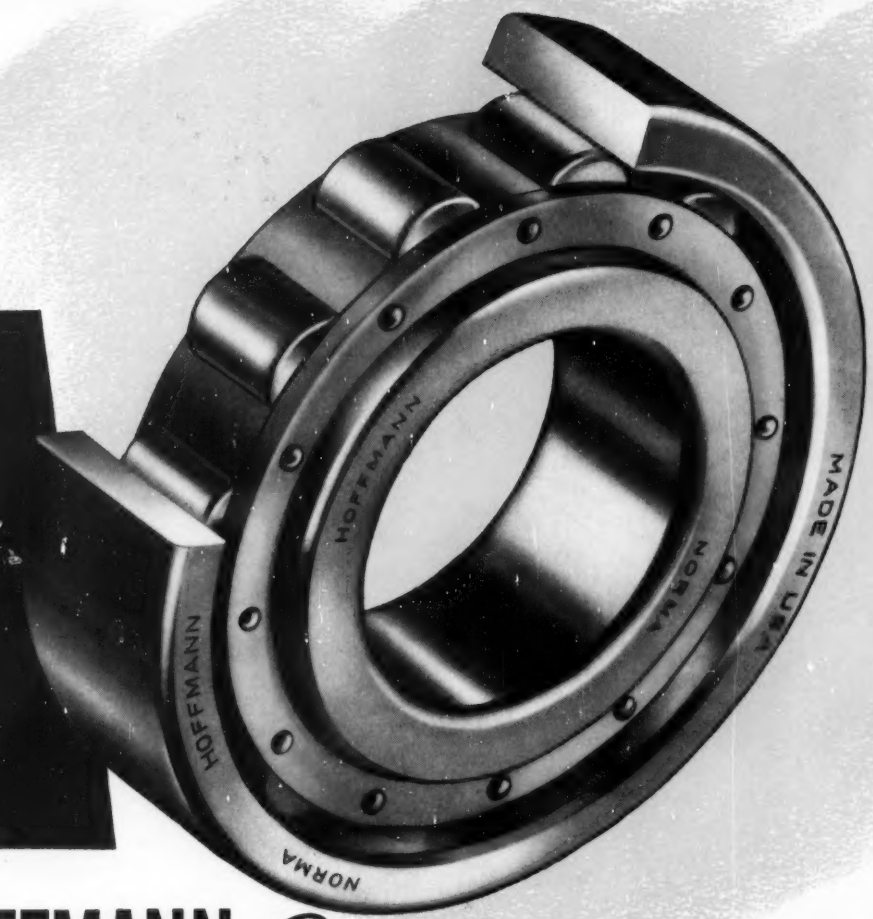
MACHINE DESIGN

A PENTON PUBLICATION

Thermostatic Bimetal Elements

Contents, Page 3

FARNSWORTH



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If your bearings must operate under such severe conditions as high speeds, heavy loads, temporary overloads, shock or vibration, then *Norma-Hoffmann* Precision Roller Bearings are your solution. Available in a wide range of both metric and inch sizes from 10 millimeter bore upward.

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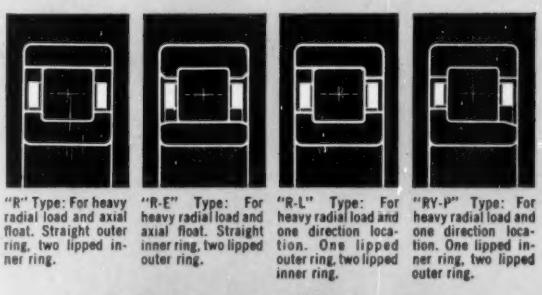
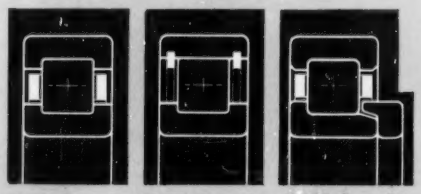


"R" Type: For heavy radial load and axial float. Straight outer ring, two lipped inner ring.

"R-E" Type: For heavy radial load and axial float. Straight inner ring, two lipped outer ring.

"R-L" Type: For heavy radial load and one direction location. One lipped outer ring, two lipped inner ring.

"RY-P" Type: For heavy radial load and one direction location. One lipped inner ring, two lipped outer ring.



"R-LL" Type: For moderate radial load and two direction location. Two lipped inner and outer rings.

"R-RR" Type: For maximum radial load at low speed. Full roller retainerless type with snap rings.

"RY-B" Type: For heavy radial load and two direction location. Two lipped outer ring, one lipped inner ring and separable guide ring.

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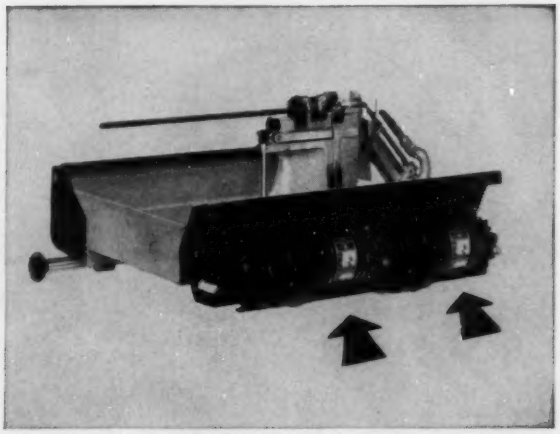
Circle 401 on page 19

"CLOSE TOLERANCES...UNIFORMITY"

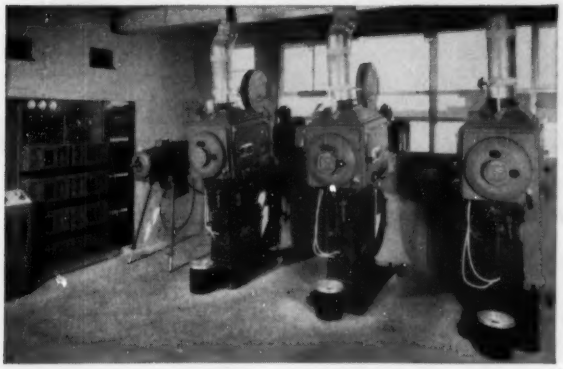
Reasons Strong Electric Corporation uses BODINE MOTORS

Bodine Type NSH-12R reducer motor

Two of these Bodine Type N reducer motors are used in each Strong Super "135" motion picture projection lamp. Strong found that only Bodine's wide selection of motors . . . over 3500 standard units, in all types and horsepower ratings (from 1/2000 to 1/6 hp) . . . could give them the speeds, power output and torque characteristics to meet their requirements. If *you* should require a *special* motor, this wide selection would hold costly modifications to a minimum.



Inside each Strong Super "135" motion picture projection lamp is this base and burner mechanism. The gear reduction ends of two Bodine Type NSH-12R motors drive negative and positive carbon feeds. Opposite ends of motors drive fans to cool lamp and stabilize arc. Dependable functioning of this automatic arc crater positioning system is important because a variation of only 1/32" can cause a loss of brightness and a change in light color.



Here are three Bodine-motor-powered Strong projection lamps ready for action . . . in the projection booth of the Miracle Mile Drive-In Theatre at Toledo, Ohio. These arc lamps, designed for use with new large screens, burn carbons at the rate of 18 to 30 or more inches per hour as compared to about 4 inches in old low intensity lamps. An automatic arc crater positioning system, driven by two Bodine motors, assures correct illumination.

Why are Bodine Motors used for Strong projection lamps? Mr. A. J. Hatch, president, The Strong Electric Corporation, Toledo, Ohio, gives these reasons:

"We needed a rugged and precision engineered motor for our Super 135 Motion Picture Projection Lamps, a motor providing dependable and trouble-free service. Only Bodine could supply motors with the speeds, power output and torque characteristics to meet our requirements. We like these motors because of their close tolerances and uniformity which makes them completely interchangeable."

Be sure *your* motor is as good as your product. For information contact Bodine Electric Company, 2258 West Ohio St., Chicago 12, Ill.

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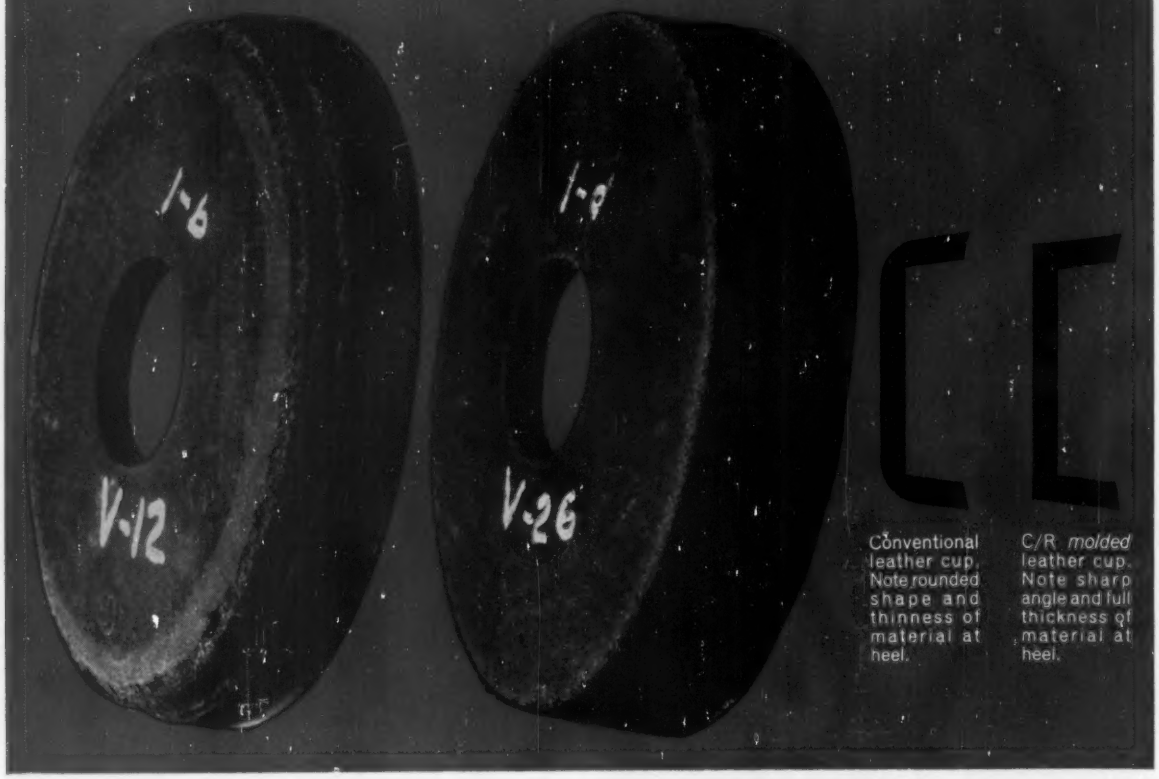
TEST PROVES C/R MOLDED CUP



Conventional leather cup. Note rounded shape and thinness of material at heel.

C/R *molded* leather cup. Note sharp angle and full thickness of material at heel.

New molded C/R cups* stand up longer... cut down replacement costs

Compare the wear on these piston cups shown in the unretouched photographs above. They were tested in a hydraulic cylinder at 6000 p.s.i. for 3000 cycles. The one at the right is a Sirvis-Conpor molded leather cup. The other is a conventional leather cup. Features of the C/R molded cup that make it so obviously superior are greater density, the sharp, rather than rounded heel, and the fact that it is pre-formed to the shape which conventional cups are forced to assume under pressure. This eliminates operational stress and flexing that conventional cups undergo, and contributes greatly to longer service life.

Right now, molded C/R cups are providing greatly increased service life in hydraulic cylinders in such heavy duty applications as farm and road building equipment and steel mill equipment at oil pressures up to 3500 p.s.i., and 150 p.s.i. in air cylinders. If you face a difficult packing problem that requires high durability and efficiency . . . it will pay you to consider this new, improved C/R design.

*Available in J.I.C. standard and other popular sizes. Write for complete size list.

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Circle 405 on page 19

THE PROFESSIONAL JOURNAL
FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

February 21, 1957
Volume 29—No. 4

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REGULAR DEPARTMENTS

Engineering News Roundup .. 5
Index 17
Meetings and Expositions 33
Helpful Literature 148
New Parts and Materials 154
Engineering Dept. Equipment .. 205
Professional Viewpoints 211
The Engineer's Library 216
Noteworthy Patents 232

POSTAGE-FREE CARDS . . . 19

for further product information and extra copies of editorial articles

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Play Ball! ..... *Editorial* 89

Product Development Costs ..... *By Peter V. Martino* 90

How to set up an estimating system for accurate prediction of costs of engineering a product from basic idea to prototype.

Scanning the Field for Ideas 101

Accurate fluid flow measurement — helical dial design — locking technique for metal tubing — wafer stem construction — castellated beam design

Simplified Drafting in Action ..... *By Jay H. Bergen* 104

Eleven basic principles that have proved to be timesaving and practical in the development of engineering drawings.

Hydraulic Servos ..... *By J. M. Nightingale* 109

Part 1 — Practical methods for analyzing typical systems.

Rotary Solenoids ..... *By J. D. Zasa* 114

Considerations influencing selection and application of ac and dc solenoids developed to produce torque through a fixed angular movement.

Thermostatic Bimetal Elements ..... *By C. F. Alban and C. C. Perry* 119

A new approach to the optimum design of temperature-sensing elements based on the concept of specific deflection for simplified problem analysis.

Design for Fatigue Loading ..... *By Joseph Marin* 124

Part 3 — Strength considerations for members subjected to both simple and combined fatigue stresses: nature of fatigue, simple fatigue stresses, complete reversal, superimposed stresses, varying stress amplitude.

Cubic Equations ..... *By G. L. Sullivan* 135

Data Sheet — A simplified method for direct and accurate solutions.

Molybdenum Alloys ..... *By R. R. Freeman and J. Z. Briggs* 137

Computer Operation ..... *By E. R. Moore* 146

Contemporary Design: Mobile air-conditioning unit, 118; dial-spindle lathe, 118.

Tips and Techniques: Layout pointer, 113; preventing ink blots, 117; calculating short cuts, 123; taping drawings, 123; simplifying wiring drawings, 123; finding tangents, 134; simplified scaling, 134; subtracting fractions, 134; printed-circuit techniques, 134

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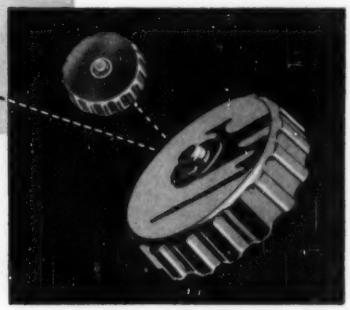
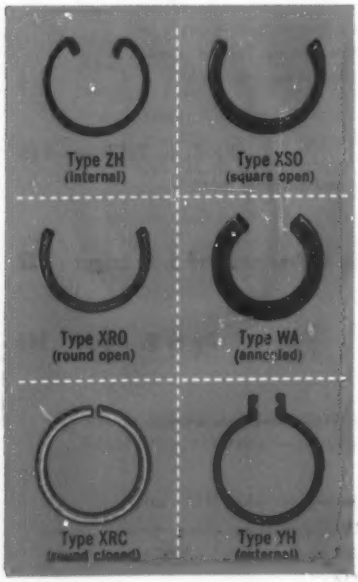


NATIONAL

RETAINING RINGS



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Circle 406 on page 19

Engineering News Roundup

Tilt-Cab Truck Carries Larger Payload

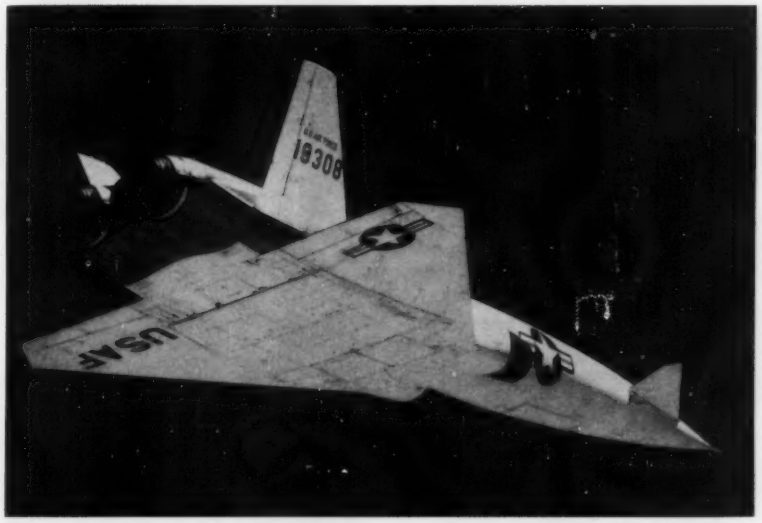
More Weight is Placed On Front Axle

DEARBORN, MICH.—A new heavy-duty Ford truck places the driver at the extreme front of the cab, above and ahead of the engine. Cab length is 80.3 in., compared to 111.1 in. for a conventional heavy truck. This shortening of the cab permits placing added weight on the front axle, freeing the rear axle of 800 to 1100 lb of weight that can be added to the payload. A 35-ft trailer can be hauled without exceeding the 45-ft overall limit of most states.

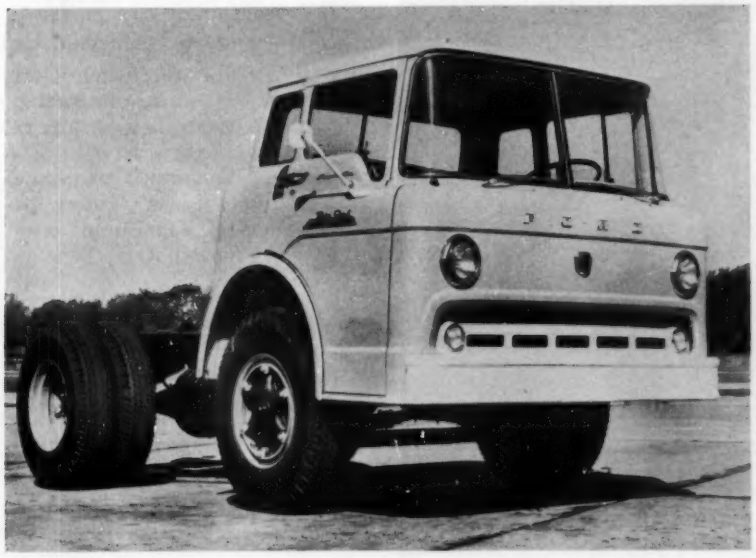
Engine and transmission are easily accessible for maintenance. The cab, hinged to the frame at the front, swings forward on spring pressure when a safety catch is released.

An added advantage of the short cab is its short turning radius, which provides easy maneuverability. Other features of the new cab are a hydraulic clutch, suspended pedals, 10 in. greater width than similar 1956 models, interior steps instead of a running board, and increased glass area.

Tilt-cab trucks are available in four wheelbase lengths, from 99 to 153 in., and with short-stroke V8 engines rated from 171 to 212 hp.



X-10 UNMANNED TEST VEHICLE, shown in one of first photos released by U.S. Air Force, has successfully completed flight-testing at high supersonic speeds. Built and tested by North American Aviation Inc., the X-10 has two turbojet engines and is provided with landing gear which enabled the craft to be recovered and reused. The tests proved out the X-10's guidance and control systems as well as the missile's aerodynamic design. X-10 is part of the Air Force program to build the SM-64 Navaho intercontinental strategic guided missile system.



Ford's new tilt cab is over 30 in. shorter than conventional heavy truck.

Facsimile Transfer in Sounder Improves Ocean Surveying

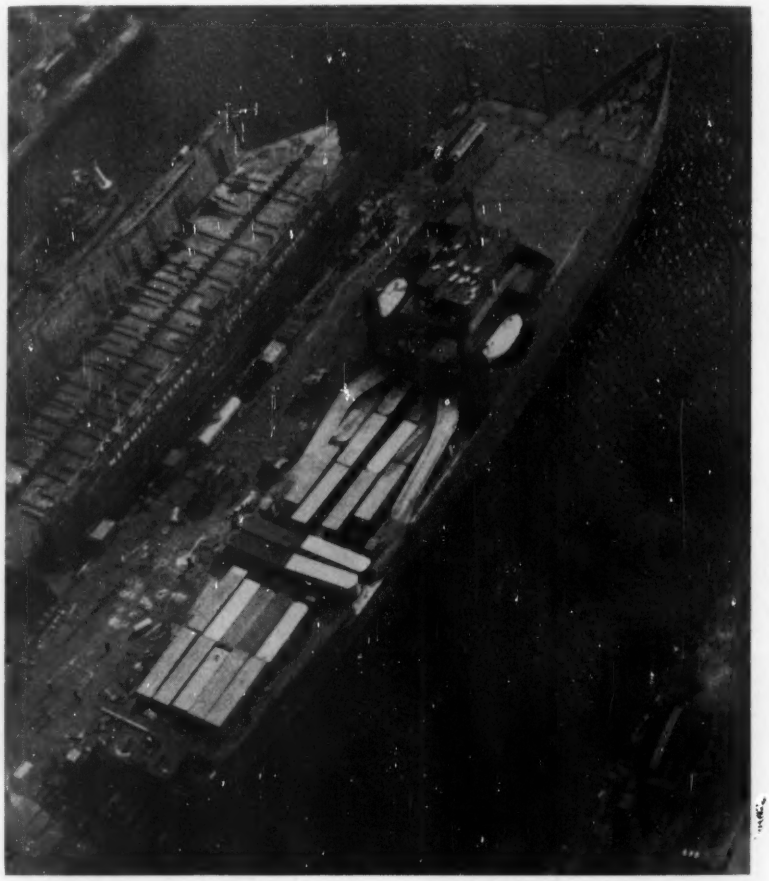
NEW YORK, N. Y.—The facsimile method of transferring pictures by radio-telegraph has been used successfully in ocean exploration. In the past four years, more than 100,000 miles of ocean floor have been sounded and sketched accur-

ately in profile. Equipment used was the Sonic Echo Sounder, part of which is a facsimile recorder. This was reported recently to the American Institute of Electrical Engineers by B. Luskin, Time Facsimile Corp.

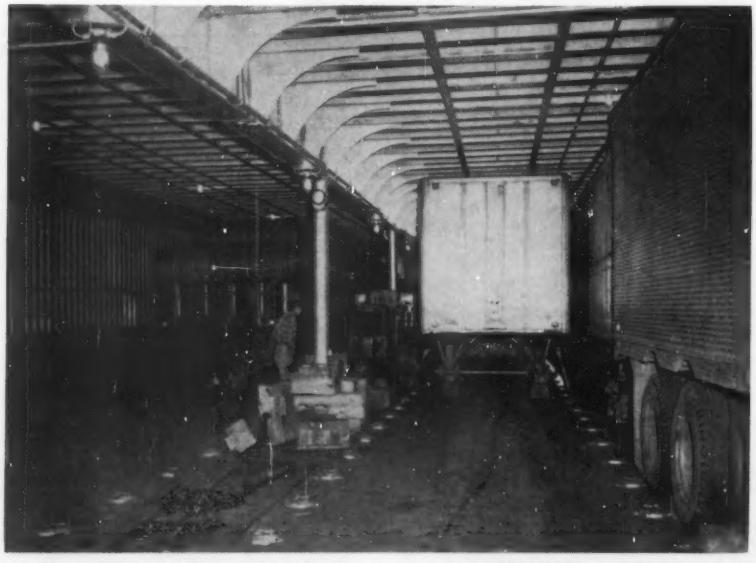
"Highly accurate facsimile recording equipment coupled to an efficient electronic sounder has produced an instrument for measuring ocean depth with a timing error of less than one fathom," according to Mr. Luskin. Prior to the introduction of facsimile, errors of plus or minus 50 fathoms had been experienced.

The large-scale expansion of the record and the precision of the recording mechanism are significant advances in hydrographic surveying. Facsimile-type depth recorders have operated around-the-clock for weeks at a time in a marine environment with negligible breakdown time.

Facsimile machines are also adaptable to other types of data recording which involve the precise display of position or time, according to Mr. Luskin. The facsimile recorder allows time marks, synchronizing pulses, and other calibration marks to be internally generated and locked into the data recording process.



Aerial view of world's largest trailership, *TMT Carib Queen,* shows arrangement of deck cargo. The ship's length is 475 ft, beam 72 ft, displacement 9040 tons, speed over 16 knots.



Trailers are backed onto the lower deck of the *Carib Queen* through two doors in the stern, then lined up in four lanes. Ship capacity is 92 trailers, 97 automobiles, 500 tons of bulk cargo. Ship also carries 12 passengers.

Biggest, Fastest Trailership Starts Trans-Atlantic Service

NEW YORK, N. Y. — The world's fastest and largest, roll-on, roll-off, self-propelled truck trailership, *TMT Carib Queen,* is now in regular trans-Atlantic service. The new ship inaugurated commercial shipment of loaded trailers between the U.S. and Europe when it left the Brooklyn Army Terminal

Front Cover

Deflection and force are the two outputs of a bimetal thermostat as a result of a temperature change. Artist George Farnsworth has shown these factors acting on a spiral bimetal element to keynote C. F. Alban and C. C. Perry's article on Page 119.

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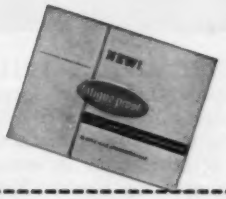

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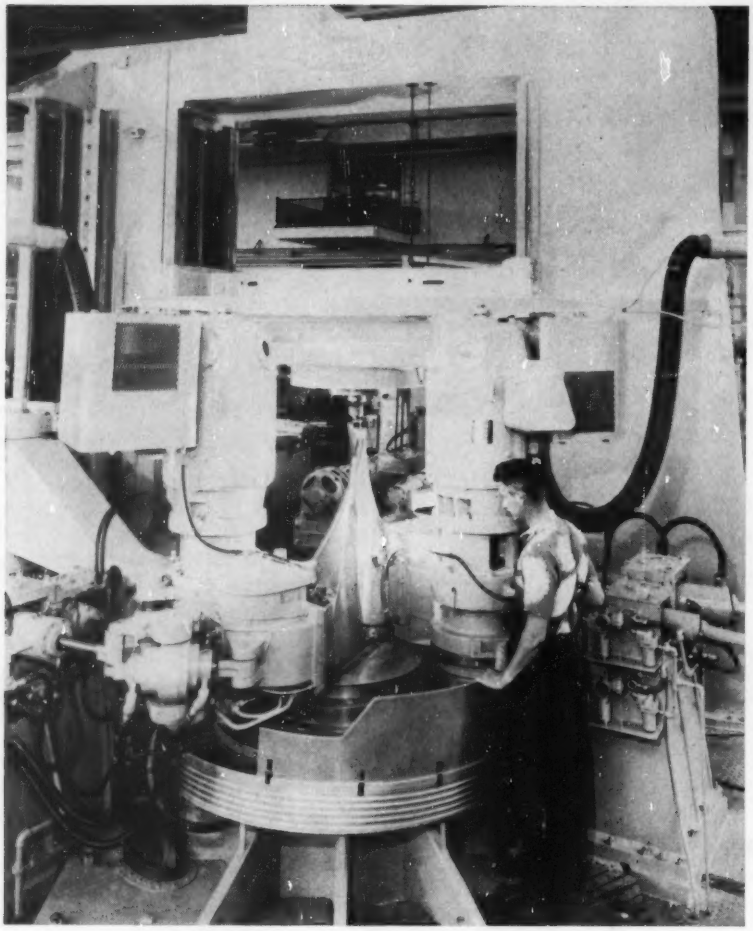
Circle 407 on page 19



LARGEST AIRFOIL MILL, claimed the only one of its type, features high-speed, automatic operation and vertical mounting of pattern and workpiece. Recently completed by Danly Machine Specialties for the NACA, the 150-ton machine now operates at Ames Aeronautical Laboratory. It reproduces in metal the complex shapes of experimental airfoils and compressor blades. Metal blanks can be 18 x 18 x 96 in. long or 8 x 26 x 96 in. long. Vertical mounting eliminates effect of bending due to weight of shapes this large. The machine rises 17 ft above floor level, fills a space 25 x 25 x 17 ft below, has 17 motors. Accuracy is ±0.004-in.

last month with cargo assigned by the Military Sea Transport Service.

On this first voyage to Europe, the *Carib Queen* carried 75 conventional truck trailers, 20 refrigerated trailers, 60 sedans, 20 jeeps and 9 amphibian trucks on its three decks. In addition, the ship can accommodate 500 tons of bulk cargo and 12 passengers.

Truck trailers are loaded on the *Carib Queen* both at the stern and from the side. At the stern, two doors swing down to become ramps over which trailers are rolled onto the lower deck. From the side, trailers are rolled over portable ramps onto the open weather deck. Loading is accomplished in 4 hr compared to 2 or 3 days for conventional loading and turn-around.

The *Carib Queen* enables U.S. shippers to load and seal trailers and consign them direct to inland points in Europe. Seals need not be broken nor the cargo disturbed in intermediate handling. Future trailership service may be co-ordinated with "piggy-back" service provided by railroads.

Topics

Automation aids archers through the medium of a machine for partial fabrication and assembly of broad head arrow points. Pneumatic units made by Mead Specialties Co. are combined in a machine that assembles a hardened steel arrowhead and the aluminum shank by which the head is attached to the arrow's wooden shaft. The shanks are automatically slotted, pressed onto the arrow points and riveted together.

• • •

Rockoon, a rocket missile, will be launched from a balloon at the Woomera rocket range in South Australia as part of the International Geophysical Year research program. The 18-ft long, 10-in. diameter rocket will take off from the balloon's launching ramp at a speed of more than 2000 mph. It will reach a height of 60 miles, carrying radio and electronic equipment for transmittal of atmospheric data to recording machines on the ground.

• • •

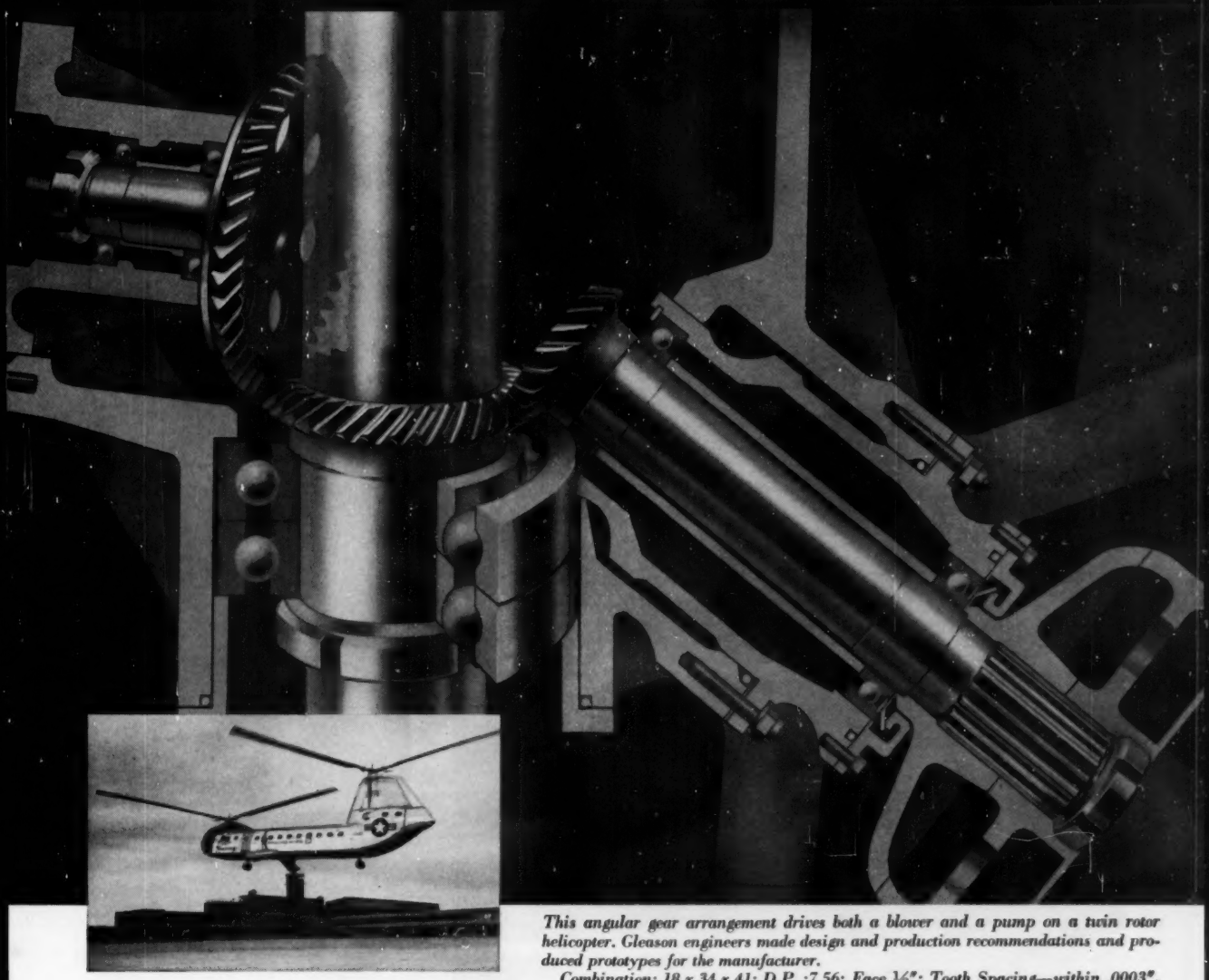
Merchant-ship reactor systems that will provide "commercially competitive" propulsive power is the goal of a joint long-range program undertaken by the Atomic Energy Commission and the Maritime Administration. Six design feasibility studies of four reactor systems will be made, the objective being to select the most promising reactor concepts for further development.

• • •

Trucks will have gas turbines before automobiles, according to R. S. McNamara, Ford Motor Co. vice president and Ford Div. general manager. Gas turbine engines would increase up-hill speed and acceleration of trucks, permitting them to keep up with other traffic. This, said Mr. McNamara, is a goal of truck manufacturers, since it would reduce highway congestion.

• • •

One of the largest lead crystals ever grown will be used to isolate neutrons of desired wavelength in diffraction experiments on polycrystalline samples. It was grown at the Naval Research Laboratory by lowering high-purity lead pellets in a crucible through a temperature gradient in a specially built furnace. The crystal weighs 56 lb, is about 14 in. long and 3½ in. in diameter.



This angular gear arrangement drives both a blower and a pump on a twin rotor helicopter. Gleason engineers made design and production recommendations and produced prototypes for the manufacturer.
Combination: 18 x 34 x 41; D.P. :7.56; Face ½"; Tooth Spacing—within .0003".

You can solve your angular power transmission problems, too!

The designers of this gear unit achieve greater flexibility within a limited amount of space by placing the drive shafts at an angle and using one source of power to drive two auxiliary units.

Perhaps a similar gear drive would make your product designs more flexible. Such bevel gear drives permit a more compact design requiring less weight and the ability to carry higher loads.

Our engineers are ready to help you work out applications for bevel and hypoid gears—just as they helped the helicopter manufacturer with the design illustrated above.

We recommended the proper gear sizes and reviewed the mountings and lubrication for the drive. Then we produced and tested prototypes of the unit.

If you would like to discuss an application with one of our representatives, please write. You will also find these Gleason Technical Handbooks helpful: 20° Straight Bevel Gear System; Spiral Bevel Gear System; ZEROL Bevel System.

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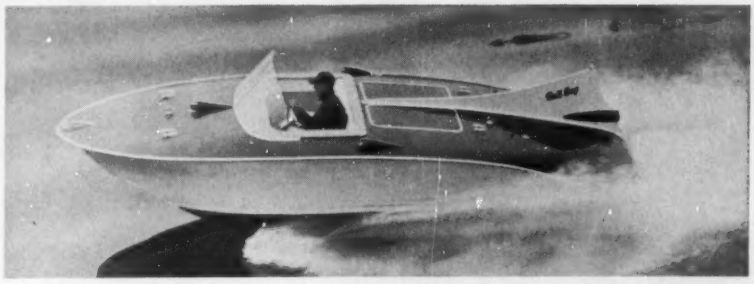
Circle 408 on page 19

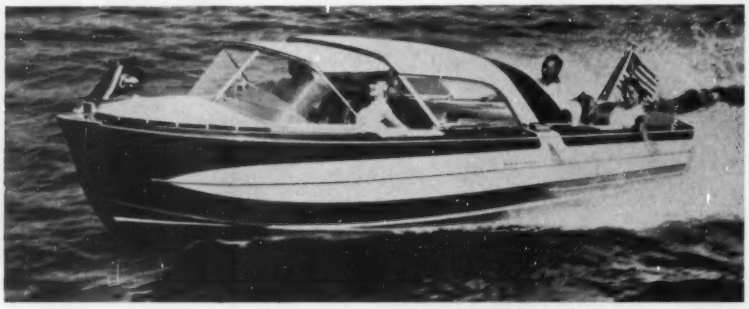
Varied Appearance and Performance Seen in Craft at Motor Boat Show

NEW YORK, N. Y.—Innovations in power plants, propulsion, hull styles and materials were highlights of the 47th National Motor Boat at the Coliseum last month. Attendance and sales lead boat and accessory builders to expect this year to exceed 1956, which had been their biggest yet. The National Association of Engine and Boat Manufacturers estimates 5,971,000 pleasure craft on U.S. waterways, a total of $1¼-billion spent at the retail level in the industry last year, and 28 million persons active in recreational boating.

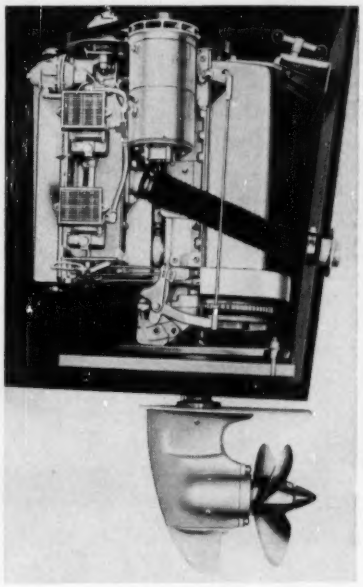
Flagship at the New York show was a 53-ft Wheeler Yacht Co. mo-



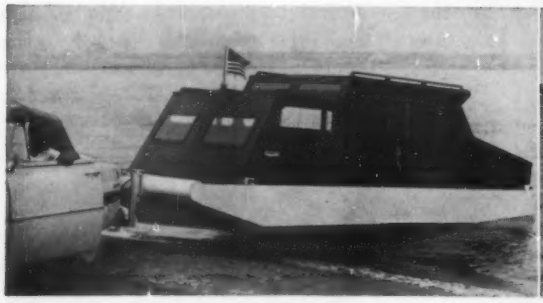
Fastest sports boat runabout is claimed for Bell Boy Bikini by its builders, Bellingham Shipyards. Powered by two 215-hp engines, Bikini is said to be capable of attaining 100 mph. Hull design is modified three-point hydroplane which gives racing-boat performance.



Most beautiful boat is said to be the Coronado model, above, built by Century Boat Co. Distinctive optional feature is Landau hardtop with aircraft-type opaque Plexiglas section, right, sliding forward to the windshield. African mahogany hull is natural color with white style lines. Wide choice of engines, including V-8's from 135 to 300 hp, make the Coronado capable of speeds over 55 mph.



Vertical-inboard-power describes the line of up-ended engines produced by Fageol Products Co. in 30, 35 and 45-hp models. Power is transmitted through a dog-type clutch to bevel gears, eliminating conventional inboard clutch, transmission and shaft log. "One Arm Bandit" remote control is a single lever that shifts gears and accelerates.



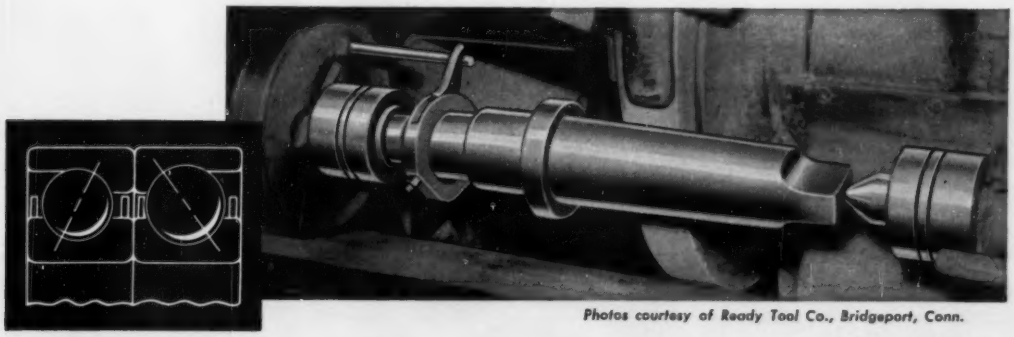
Amphibious trailer-cruiser, the Sportsman, introduced by Neptuna Corp., has retractable wheel with eight-ply truck tires, puncture-proof tubes and electric brakes. A houseboat-type craft, Sportsman includes a built-in bar.

Utility hardtop made by The Anchorage has hull of glass fiber and polyester resin formed to give maximum rough-water performance. Extreme flare forward turns down spray and air to keep interior dry.

FACTS

about

NEW DEPARTURE BALL BEARINGS



Photos courtesy of Ready Tool Co., Bridgeport, Conn.

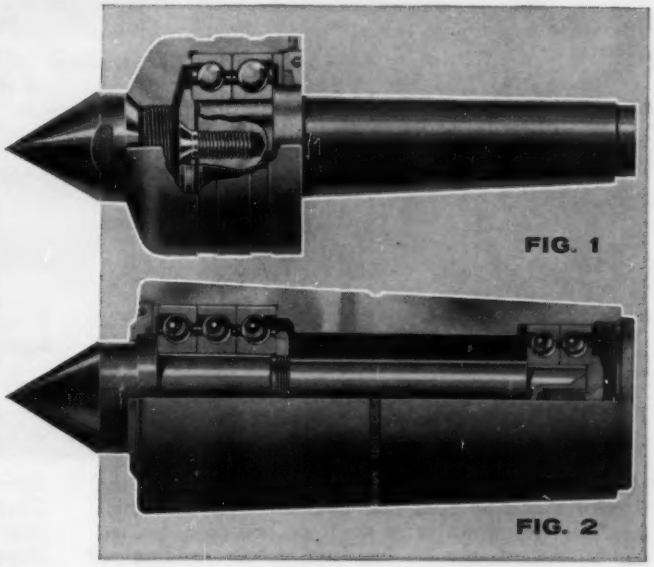
PRELOADED BALL BEARINGS HELP CENTER MAKERS GUARANTEE ACCURACY TO WITHIN .000050"!

Accuracy . . . *to within less than .000050" total indicator run-out!* That's the performance live centers designed around New Departure preloaded ball bearings deliver!

Such super accuracy of work stems from *extreme rigidity* . . . the unsurpassed ability of these preloaded duplex ball bearings to handle combination loads with minimum deflection.

In live center applications, New Departure ball bearings with medium and high contact angles are mounted duplex and positively clamped together to assure the correct predetermined preload condition. As work expansion increases the thrust load, radial centering becomes more rigid and accuracy is precisely maintained.

New Departure ball bearings for live center applications are made to ultra-precision tolerances. Smooth operation with low frictional loss is assured, as well as continuity of accuracy throughout long life. Write for further details.



(Fig. 1) Shank type center in which New Departure ABEC 7 specification duplex ball bearings support grinding loads with undiminished accuracy throughout long use.

(Fig. 2) Enclosed spindle center designed around five New Departure ultra-precision preloaded duplex ball bearings.

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del sold for $110,000. The owner wants to put an electric dish washer in the galley. In a total of 448 craft exhibited, 29 per cent had wooden planked hulls, 21 per cent aluminum, 19 per cent sheet plywood, 18 per cent plastic, 12 per cent molded plywood and 1 per cent steel.

Besides the items shown in this picture summary, new and interesting developments included:

The biggest glass fiber boat ever shown at this annual exposition—a 41-ft auxiliary sailboat by Coleman Boat and Plastic Co.

An ice boat driven by an air propeller, made by MacDonald-Bernier Co.

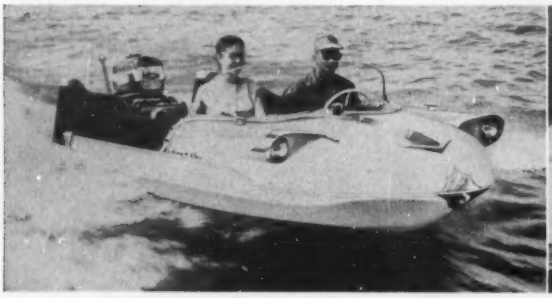
The first production inboard cruiser to have hull, decks and bulkheads welded into one integral unit, the product of Kehrig Mfg. Co.

Stretched-hull construction with one-piece bottom and side structure on aluminum runabouts.

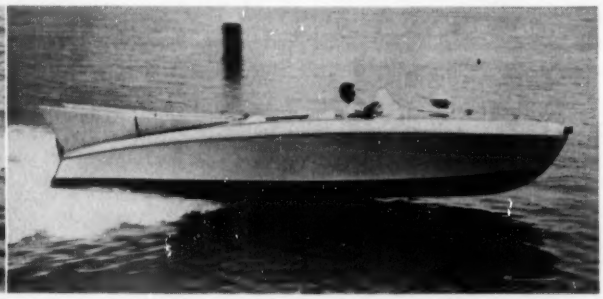
A 2-hp "Pony Power" children's outboard motor, weighing 29 lb, air-cooled, made by West Bend Aluminum Co.

"Banana Peel," 360-degree turn-around water skis made by Hedlund Mfg. Co.

Hydro-Glider, towed by motorboat, leaves the water at 20 mph airspeed with rotor turning in autorotation. Gyro-Boat, also made by Bensen Aircraft Corp., uses boat hull instead of pontoons. Cruising speed for these craft is 30 mph; top speed 60 mph; landing speed 7 mph. Operators need no license.



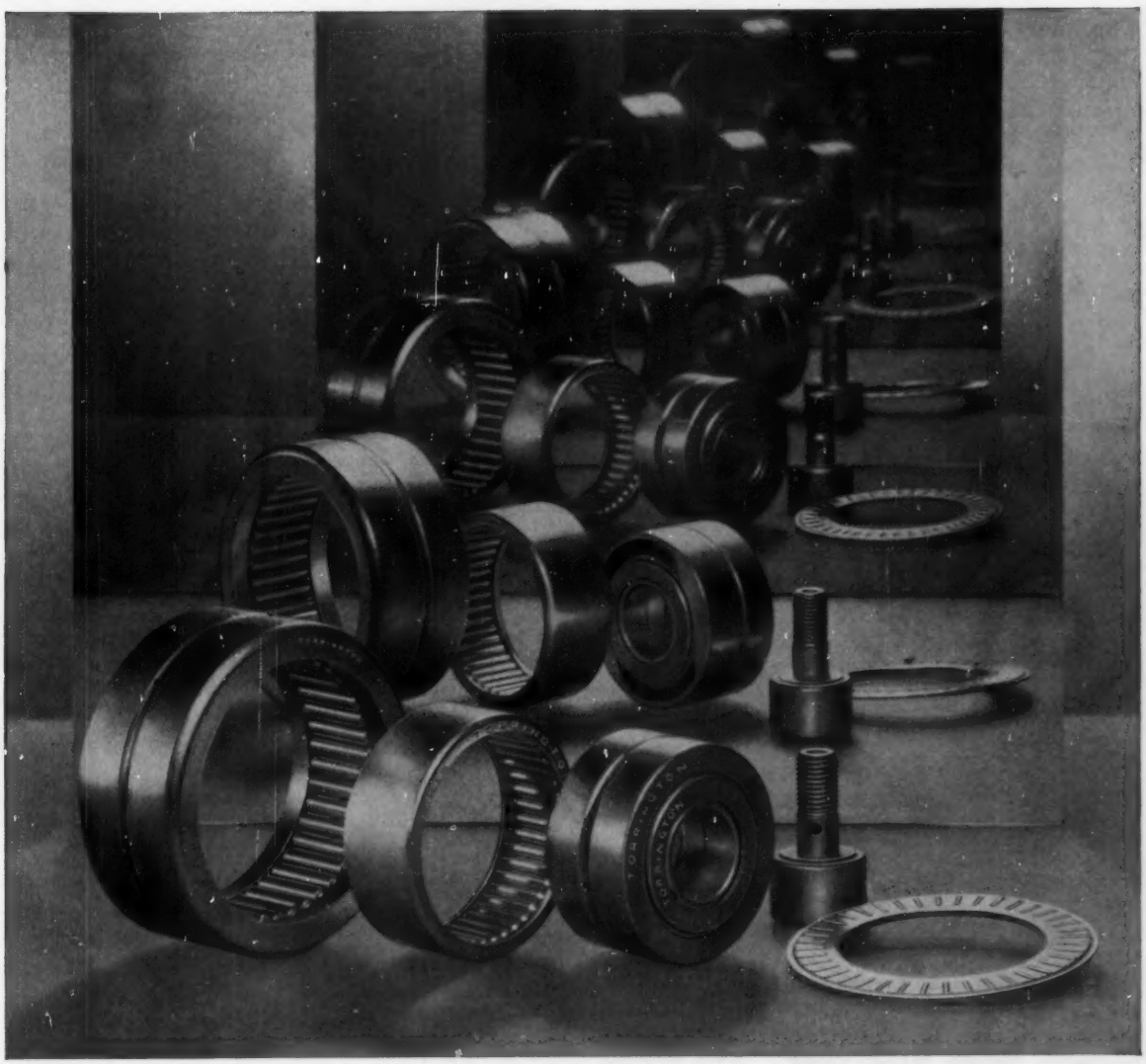
Automotive influence in boat styling is illustrated in the Meteor model by Lone Star Boat Co. Glass fiber hull has rear fins which carry ski tows, and twin docking lights forward. Interior has foam rubber padding on dash and side panels. Meteor is made in four colors.



Speed and style are featured in the Aqualifer model by Ancarrow Marine, Inc. Two 300-hp engines drive the boat at 60 mph on monoplane bottom hull shape. Aqualifer carries eight in two cockpits, has four glove compartments, safety toe-rail around deck.

American Institute of Electrical Engineers has announced the nomination of Walter J. Barrett as president. Nomination was made at the Institute's winter general meeting in New York City. Mr. Barrett, transmission engineer of New Jersey Bell Telephone Co., will serve as 1957-58 AIEE president. He had been the treasurer.

The 1956 Edison Medal was presented to Comfort A. Adams during the opening general session of the AIEE meeting. Dr. Adams was cited for his "pioneering achievements in the development of alternating current electric machines and in electrical welding; for vision and initiative in the formation of engineering standards organization and for eminence as an educator and consulting engineer." Dr. Adams is professor of engineering emeritus, Harvard University, where he began his teaching career in 1891. He has been a member of AIEE since 1894 and served as president in 1918-1919. He was the recipient of the Lamme Medal for 1940.



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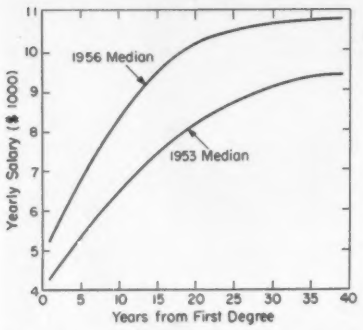
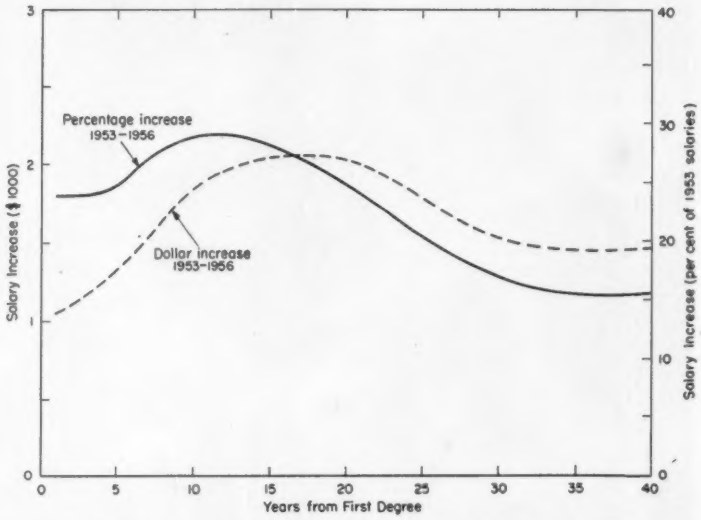


How pay for the "median engineer" rose from 1953 to 1956.


Percentage increase 1953–1956
Dollar increase 1953–1956
Salary Increase ($ 1000)
Salary Increase (per cent of 1953 salaries)
Years from First Degree

Increase in engineers' salaries from 1953 to 1956. Largest dollar increase was for engineers with 10 to 25 years of experience, but five year younger men got the biggest percentage boost. Figures are for the median pay scale in industry related to number of years from first engineering degree or entry into the profession.

First data from 1956 EJC salary survey shows

Engineers' Pay: Up 23% in 3 Years

NEW YORK, N. Y.—Industry's wallet has opened widest to the middle-aged engineer over the past three years. But young engineers and new graduates continue to pace the rising salary trends.

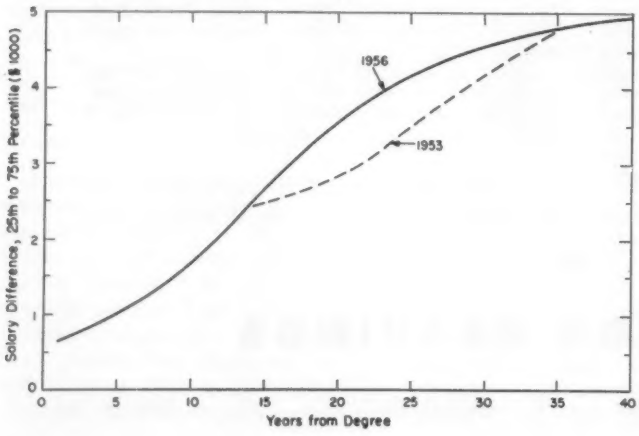
Engineers with 10 to 25 years of experience got the biggest dollar pay boost, according to preliminary figures from the 1956 Engineers Joint Council salary survey. But percentage increases were highest for men about five years younger.

Engineers have received an average pay raise of about 23 per cent in three years, if the age pattern of the 1953 EJC survey sample is repeated.

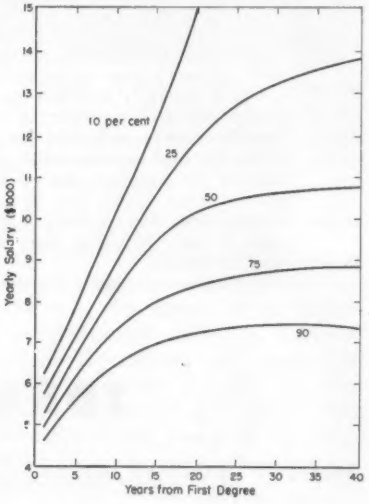
New graduates and young engineers (less than five years' experience) continued to press hard. Although mid-range men beat the 25 per cent pay-boost marker,

(*Continued on Page* 22)

"Spread" in pay between highest and lowest 25 per cent of engineers (25th and 75th percentile). Top-pay engineers with 15 to 35 years of experience gained ground.



Percentile salary levels for engineers in industry, based upon preliminary data from the 1956 Engineers Joint Council salary survey. Traditional five-year figure salary was reached in 1956 by half the engineers surveyed after 18 years of experience.



New Rokide* Coatings Resist Heat and Abrasion

Rokide spray coatings help solve many high temperature and wear problems

WITH the rapid increase in modern high temperature applications there has been a corresponding increase in demands for resistant materials. Norton ROKIDE spray coatings are meeting such demands with great success. These hard, adherent crystalline refractory oxides offer many important advantages. For example:

They are both thermally and electrically insulating . . . Their hardness, chemical inertness and stability in combustion temperatures provide high resistance to excessive heat, abrasion, erosion and corrosion. Their high melting points and low thermal conductivities reduce the temperatures of the underlying materials and permit higher operating temperatures.

ROKIDE Coatings vs. Stainless Steel

Analyses of Norton ROKIDE spray coatings and of stainless steel reveal interesting comparisons. While less dense than the bare steel, the ROKIDE coatings are very much harder, have considerably higher melting points and are very much lower in thermal conductivity and thermal expansion.

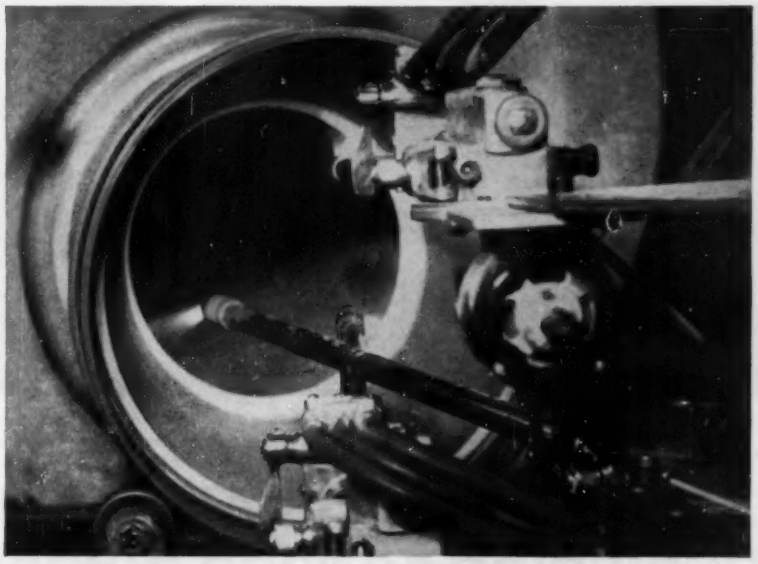
Proof

There are three Norton ROKIDE coatings: ROKIDE "A" aluminum oxide, ROKIDE "ZS" zirconium silicate and ROKIDE "Z" stabilized zirconia. These have been proved in such critical applications as reaction motors, as well as in AEC projects.

ROKIDE spray coatings are also helping to solve industrial problems involving: Electrical insulation • Thermal barriers • Electronic applications • Bearing surfaces • Erosion protection • Corrosion retardation • Chemical barriers • Positioning medium • Material up-grading • Altering emissivity and characteristics of surfaces • Surface catalytic activity • General wear resistance.

Although ROKIDE coatings are most commonly applied to metals they are effective on other materials, such as ceramics and certain plastics. Thicknesses of the coatings generally range from .005″ to .05″.

For more detailed information on ROKIDE coatings, use the coupon.



ROKIDE Spray Coatings are applied in a molten state by means of a metalizing type spray gun.* The oxide is fed into the gun in rod form at a carefully controlled rate. The coatings can be applied to parts of any size and to all shapes accessible to the spray gun equipment. Multiple gun set-up shown in illustration.

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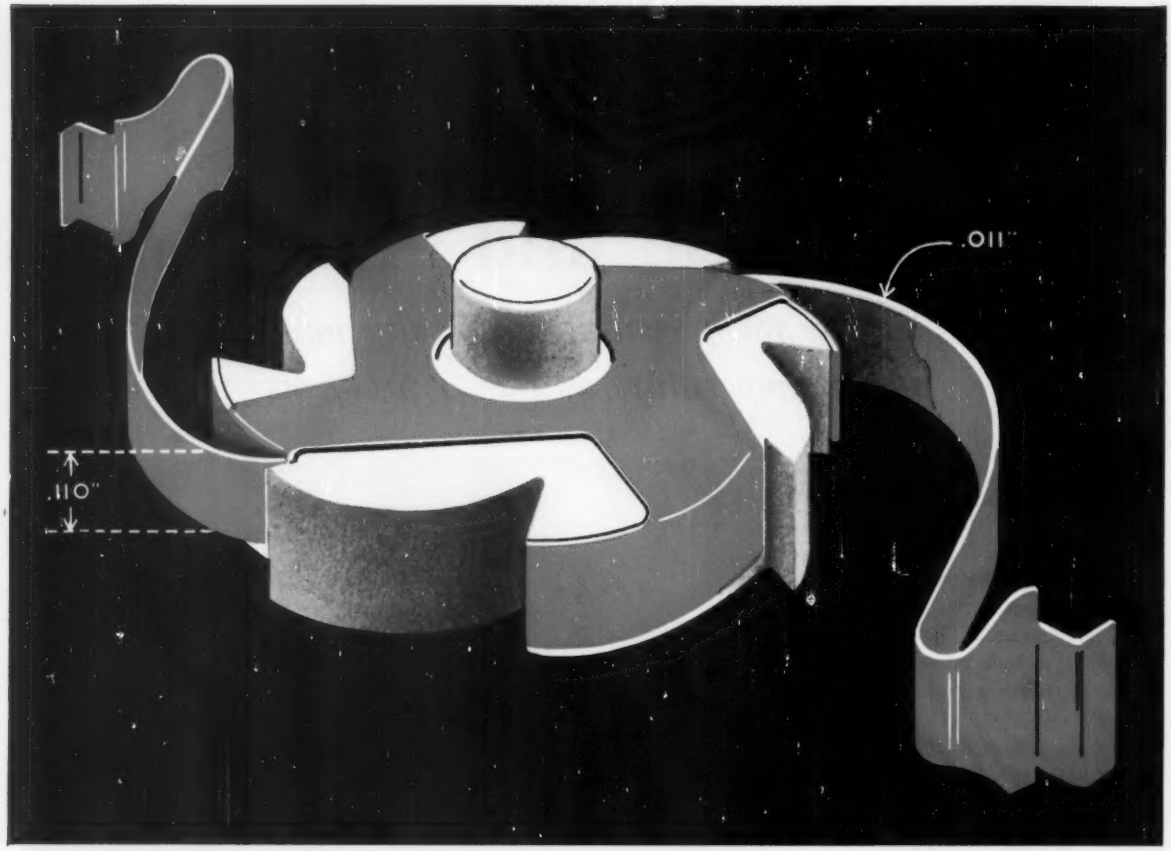
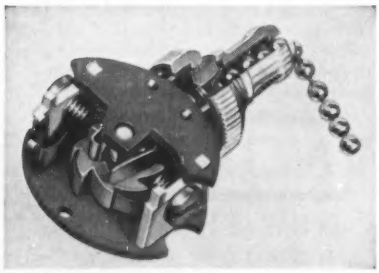


Enlargement showing the contact springs at the "heart" of one model of the Levolier® switch mechanism. Levolier switches are used in industrial and commercial lighting, in heavy-duty industrial sockets, in appliances, fixtures, etc.

The Anaconda alloy tailored for this punishing service actually costs less



Cutaway of Levolier Switch No. 41 shown approximately actual size.

THE PROBLEM: The McGill Manufacturing Company, Inc., Valparaiso, Indiana, was interested in a desirable substitute for a premium copper alloy used in contact springs for their widely known Levolier switch mechanisms. Unexcelled quality had to be maintained with a new alloy that would help hold prices against rising costs. As these switches are designed for long service and heavy-duty industrial service, the spring material has to be tough and durable.

THE SOLUTION: In 1952, McGill discussed the problem of an alternate spring material with a metallurgical engineer from The American Brass Company. After an analysis of the requirements, a special Anaconda alloy was offered—Ambronze-422, rolled to spring temper.

Samples were prepared and tested by McGill and Underwriters' Laboratories. The material performed satisfactorily in standard tests—current carrying capacity, 6 amps at 125 volts d.c.—readily exceeded the requirements of 75,000 cycles, or 150,000 individual operations.

In production, the new Anaconda alloy also performed satisfactorily. It was necessary to make only one minor die-forming change. McGill received a desirable saving in material costs—product quality remained high—and the material was available as needed to maintain production.

FREE TECHNICAL SERVICE: This is another example of the Anaconda technical service available to metal users. Sometimes a new alloy is required—other times a variation of a standard alloy will do the job. The Technical Department of The American Brass Company, through its day-to-day work with a wide variety of metal problems, offers a tremendous breadth of experience, which is at your disposal. See your American Brass Company representative or write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario. 5004

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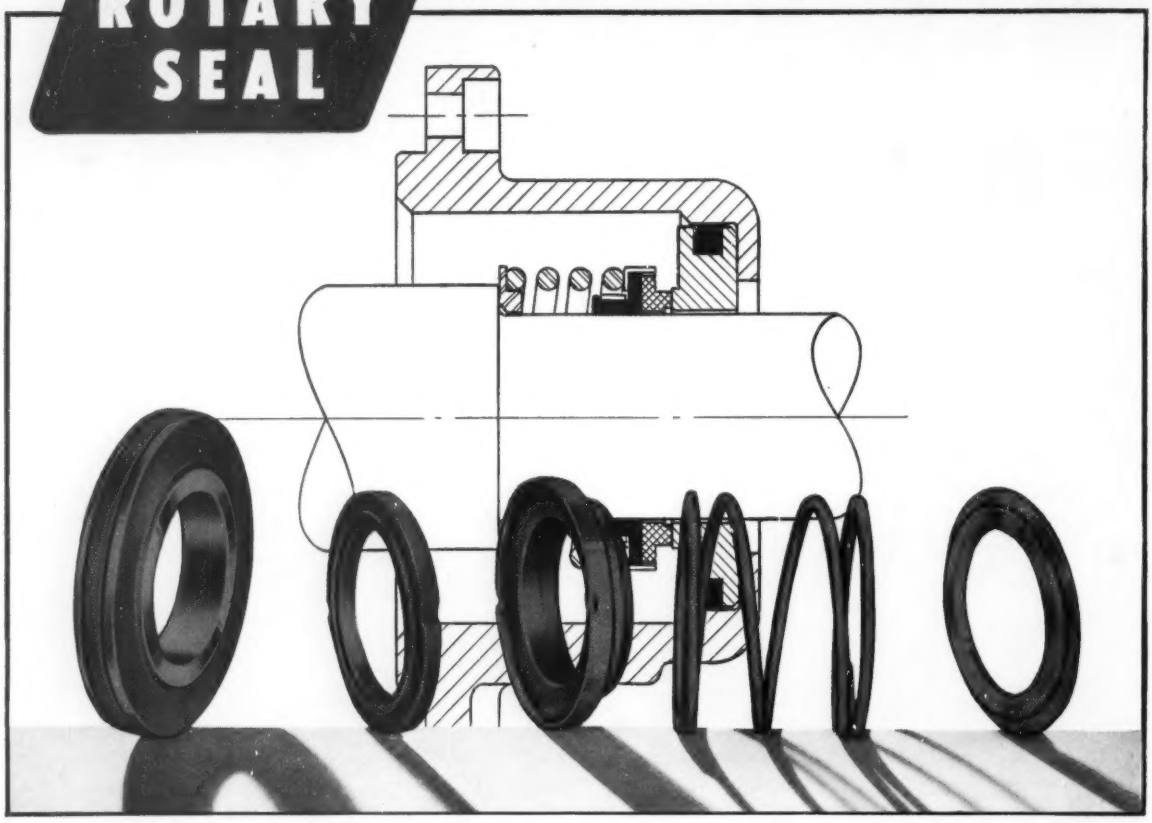

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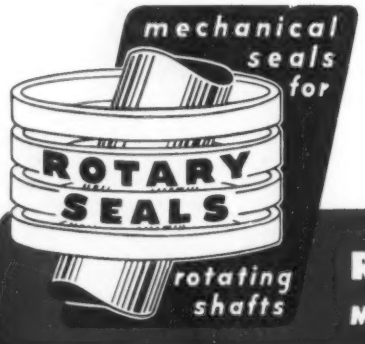

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Circle 575 on page 19

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SUBJECT INDEX

Editorial and Advertising content classified by subject and listed by page number for convenience when studying specific design problems. For further information on subjects advertised, refer to advertisement and circle Item Number on a Yellow Card—following page.

Actuators, Edit. 181; Adv. 191
Adhesives, Adv. 39
Air conditioner, quick-mounting, Edit. 118
Aluminum and alloys, Adv. 151, 157
Amplifiers, Edit. 157

Balls, Adv. 11, 31, 55
Beams, Edit. 103
Bearings, ball, Adv. 16A, 55, 185, 231
  miniature, Adv. 16A, 231
  needle, Adv. 13, 21, 141, 201
  rod-end, Adv. 237
  roller, Adv. inside front cover, 30, 185, 196, back cover
  sleeve, Adv. 29, 237
  thrust, Edit. 190
Belts, conveyor, Adv. 216
  transmission, Adv. 180, 182
Bimetals, Edit. 119
Blowers, Adv. 28
Books, Edit. 216
Boosters, pressure, Adv. 50
Brakes, Adv. 47, 86, 165, 198, inside back cover
Brass (see copper and alloys)
Bronze (see copper and alloys)
Brush holders, Adv. 241
Brushes, commutator, Edit. 175

Camera, television, small, Edit. 22
Cams, Adv. 141
Castings, die, Adv. 54, 62, 233
  iron, Adv. 167
Chain, transmission, Adv. 79, 227
Circuit components, Edit. 203
Clamps, Adv. 242
Classified ads, Adv. 176, 219, 236, 244
Clutches, Edit. 164, 234; Adv. 47, 86, 165, 192
Coatings (see also Finishes)
Coatings, protective, Adv. 15, 225
Cold heading, Adv. 240
Compressors, Adv. 223
Computer components, Edit. 198
Computer operation, Edit. 146
Connectors, electric, Edit. 154, 162; Adv. 40
Control systems, pneumatic, Adv. 241
Controls, automatic, Adv. 166
  cable, Adv. 244
  electric, Edit. 154; Adv. 35, 37, 52, 181, 208
  hydraulic, Edit. 167
  pneumatic, Adv. 155, 215
Copper and alloys, Adv. 16, 248
Costs, product development, Edit. 90
Counters, Edit. 170; Adv. 202
Couplings, shaft, Edit. 160, 200
Covers, way, Edit. 154
Cubic equations, Edit. 135
Cylinders, hydraulic, Edit. 154; Adv. 72
  pneumatic, Edit. 154

Dials, Edit. 102
Drafting, simplified, Edit. 104
Drafting equipment, Edit. 205; Adv. 36, 48, 61, 238, 240, 243
Drives, adjustable speed, Adv. 161, 203, inside back cover
Ducting, flexible, Adv. 205

Electric equipment (see specific type)
Engineering department (see Drafting)
Engines, Adv. 204
Extrusion, Adv. 151, 217

Facilities, general, Adv. 88, 242
Fasteners, blind, Adv. 27
  bolts, nuts, screws, Edit. 157, 170, 178, 184, 190, 211; Adv. 32, 160, 173, 174, 188, 194, 236, 238, 240, 243, 244
  pin, Adv. 199
  retaining rings, Adv. 4
  rivet, Adv. 164
Fatigue loading, Edit. 124
Fiber, Adv. 44
Filters, Adv. 45
Finishes (see also Coatings)
Finishes, protective, Edit. 203
Fittings, pipe, tube and hose, Adv. 64, 77, 143, 178
Forgings, Adv. 209
Friction materials, Adv. 234

Gage protectors, Edit. 162
Gages, pressure, etc., (see also Instruments), Adv. 170
Gaskets, Adv. 158
Gears, Adv. 9, 24, 33, 34, 156, 214, 241
Generators, electric, Edit. 167
Glass, Adv. 193

Heads, preformed steel, Adv. 71
Heat-resistant alloys, Edit. 172; Adv. 46, 51
Heaters, Adv. 200
Hose, nonmetallic, Adv. 64, 143
Hydraulic equipment (see specific type)

Instruments, Edit. 5, 101, 181, 205
Insulation, Edit. 103

Lathe, dial-spindle, Edit. 118
Lighting, Adv. 239
Locks, Adv. 240
Locomotive, gas-turbine, Edit. 28
Lubricants, Adv. 26, 41, 243
Lubrication equipment, Edit. 172

Machines (see specific type)
Magnets, Edit. 187
Meetings, Edit. 33
Metals (see also specific type)
Metals, Adv. 46, 213
Molybdenum and alloys, Edit. 137; Adv. 179
Motor boats, Edit. 10
Motors, electric:
  fractional and integral hp, Edit. 184; Adv. 1, 60, 68, 82, 168, 171, 190, 203, 206, inside back cover
  gearmotors, Adv. 203, inside back cover
Motors, hydraulic, Adv. 50, 57
  pneumatic, Adv. 186

MACHINE DESIGN is indexed in Industrial Arts and Engineering Index Service, both available in libraries, generally

Mountings, vibration and shock, Adv. 70

Nameplates, Edit. 160

Packings, Adv. 2
Plastics, Edit. 154; Adv. 44, 65, 80
Plastics molding, Adv. 139, 229
Plugs, Adv. 238
Pneumatic equipment (see specific type)
Powder metallurgy, Adv. 42
Pulleys, Adv. 31
Pumps, Adv. 162, 190
  hydraulic, Adv. 50, 57, 72, 76, 172
  pneumatic, Adv. 195

Reducers, speed, Adv. 33, 34, 156, 163, 210
Regulators, pressure, Adv. 45
Relays, Edit. 187, 200; Adv. 147
Rubber, Adv. 75, 84, 145, 184

Salary, engineers', Edit. 14
Screws, power, Adv. 191
Seals, Adv. 239
  mechanical, Edit. 232, 234; Adv. 16B, 69, 175, 212, 237
Servos, Edit. 109, 157
Sheaves (see Pulleys)
Ship, trailer-carrying, Edit. 6
Silicones, Adv. 145, 184
Solenoids, rotary, Edit. 114
Spindles, Adv. 235
Splines, ball-bearing, Adv. 191
Springs, Adv. 66
Sprockets, Adv. 79, 221
Starters, Adv. 52
Steel, Edit. 164. 7, 23, 25, 51, 58, 63, 217
  stainless, Adv. 78, 183, 189
Switches, Edit. 192; Adv. 35, 85, 220
Synchros, Edit. 195
Systems, hydraulic, Adv. 50, 57, 72

Tachometers, Edit. 188
Timers, Edit. 200; Adv. 166
Tips and techniques, Edit. 113, 117, 123, 134
Transmissions, adjustable speed, Adv. 187, 200
Truck, tilt-cab, Edit. 5
Tubing, Edit. 102, 195; Adv. 74, 83

Valves, Edit. 188, 198, 232; Adv. 238, 247
  hydraulic, Edit. 167; Adv. 50, 57, 72, 232
  pneumatic, Adv. 155, 215

Waveguide components, Edit. 178
Weighing equipment, Adv. 218
Welding, Adv. 149
Weldments, Adv. 88

USE A YELLOW CARD *for More Information . . .*

CIRCLE ITEM NUMBERS—Throughout the magazine, each advertisement carries an Item Number for use in requesting further information. All product descriptions, announcements and Helpful Literature items are also numbered, and for greater convenience are indexed below by Item Numbers.

EDITORIAL CLIPSHEETS—So you won't have to "clip" this issue, we'll be glad to send a personal copy of any article as long as the supply lasts. Just fill in the page number and title of article in the place provided on the Yellow Card.

Index to New Parts & Helpful Literature

BY ITEM NUMBERS

HELPFUL LITERATURE— descriptions start on page 148

	ITEM NUMBER
Centralized Lubrication	650
Centrifugal Pumps	651
Heat Exchanger	652
Gaskets & Shims	653
Marking Tools & Equipment	654
Absorption Dynamometers	655
T & T-Slot Bolts	656
Shear Pin Sprockets	657
Small-Engine Starter	658
Servo Building Blocks	659
Tube Fitting Adapters	660
Permanent Magnets	661
Self-Locking Clinch Nut	662
Thread Gaging Guide	663
Vertical Pumps	664
Strain Gages & Accessories	665
Rectilinear Recorder	666
Electronic Wire	667
Temperature Control	668
Pneumatic Transmission System	669
Electrical Contacts	670
Mercury Switch Controls	671
Resin Casting Compounds	672
Tubular Screen Filters	673
Centrifugal Pumps	674
V-Belts	675
Packaging with Plastics	676
Airborne Equipment Switches	677
Stainless Steel Fasteners	678
Teflon-Lined Pipe	679
Fluid Power Equipment	680
Temperature Chart	681
Hydraulic Hose Fittings	682
Terminals & Splices	683
Analog Computers	684
Balancing Machines	685
Ceiling Lighting	686
Oil-Tight Pushbuttons	687
Molded Rubber Products	688
Ceramics	689
Switches	690
Autotransformers	691
Infrared Weapons Systems	692
Electrical Insulation	693
Variable Pitch Drives	694
Seamless Tubing	695
Nickel Cadmium Batteries	696
Pushbuttons	697
Small Socket Screws	698
Data Handling System	699
Limit Switches	700
Roll Neck Bearings	701

NEW PARTS & ENGINEERING EQUIPMENT— descriptions start on page 154

	ITEM NUMBER
Air Cylinders	702
Wire Splice	703
Plexiglas Sheets	704
Way Cover	705
Pushbuttons and Accessories	706
Set Screws	707
Servo Amplifiers	708
Flexible Couplings	709
Plastic Nameplates	710
Gage Protector	711
Socket Mounting	712
Miniature Slip Clutch	713
Fatigue-Resistant Steel	714
Hydraulic Manifold	715
Motor-Generator Set	716
Clinch Nuts	717
Electronic Counter	718
High-Temperature Alloy	719
Lubricator	720
Graphitic Brushes	721
Setscrew	722
Waveguide Components	723
Panel Meters	724
Actuators	725
Fan Motors	726
Self-Sealing Screws	727
Miniature Sensing Relays	728
Ceramic Magnet Material	729
Tachometer-Generator	730
Solenoid Valve	731
Thrust Bearing	732
Anchor Nut	733
Pressure Switch	734
Thin-Wall Tubing	735
Stepping Synchro	736
Needle Valves	737
Ball and Disk Integrators	738
Flexible Coupling	739
Time-Delay Relay	740
Circuit-Component Kit	741
Ceramic Gold Finish	742
Plotting Instrument	743
Rocket Flight Simulator	744
Power Supply	745
Stem Thermometer	746
Lettering Set	747
Chart Recorder	748

MACHINE DESIGN
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401	426	451	476	501	526	551	576	601	626	651	676	701	726	751
402	427	452	477	502	527	552	577	602	627	652	677	702	727	752
403	428	453	478	503	528	553	578	603	628	653	678	703	728	753
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Permit No. 36
CLEVELAND, OHIO

BUSINESS REPLY CARD
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Cleveland 13, Ohio

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NEW

KAYDON THIN SHELL NEEDLE BEARINGS

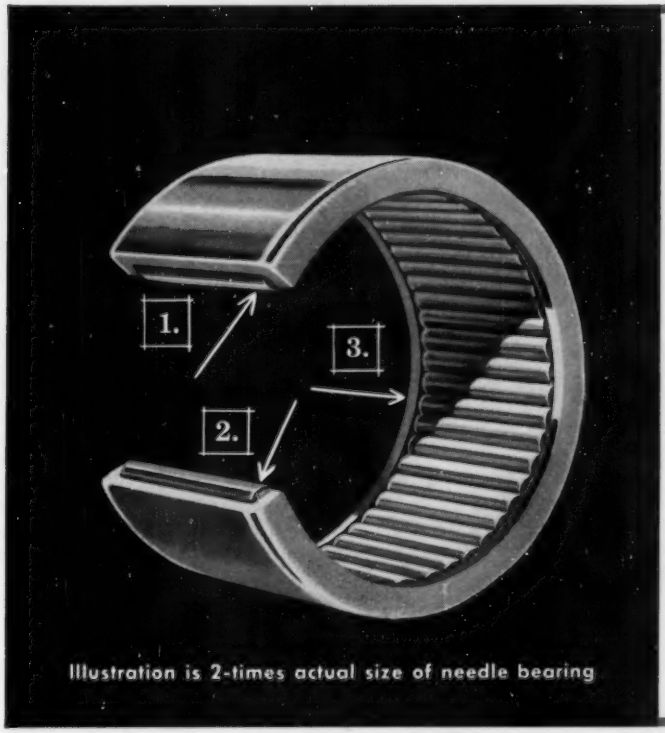
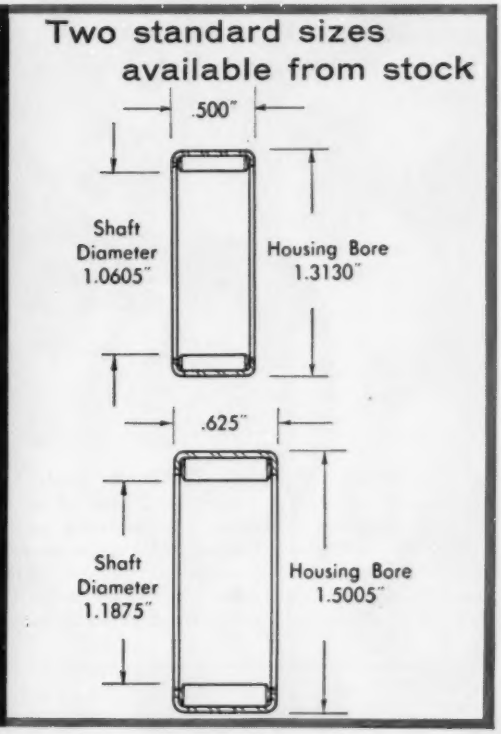


Illustration is 2-times actual size of needle bearing



You get these Kaydon design advantages:

1. Greater effective length needle rollers for MORE CAPACITY (41% on ½" width) . . . LONGER LIFE (2.8 times as much on ½" width) 2. Simplified construction that SAVES you money 3. Pre-packed lubrication that SAVES assembly time.

These new thin-shell bearings were developed with the co-operation of the FORD MOTOR COMPANY for use in FORD-O-MATIC and MERC-O-MATIC automatic transmissions

Kaydon's new thin-shell needle bearing gives more of everything — *more economy . . . more capacity . . . plus longer life* than any other comparable bearing. That's because of Kaydon's greater effective length of spherical end rollers.

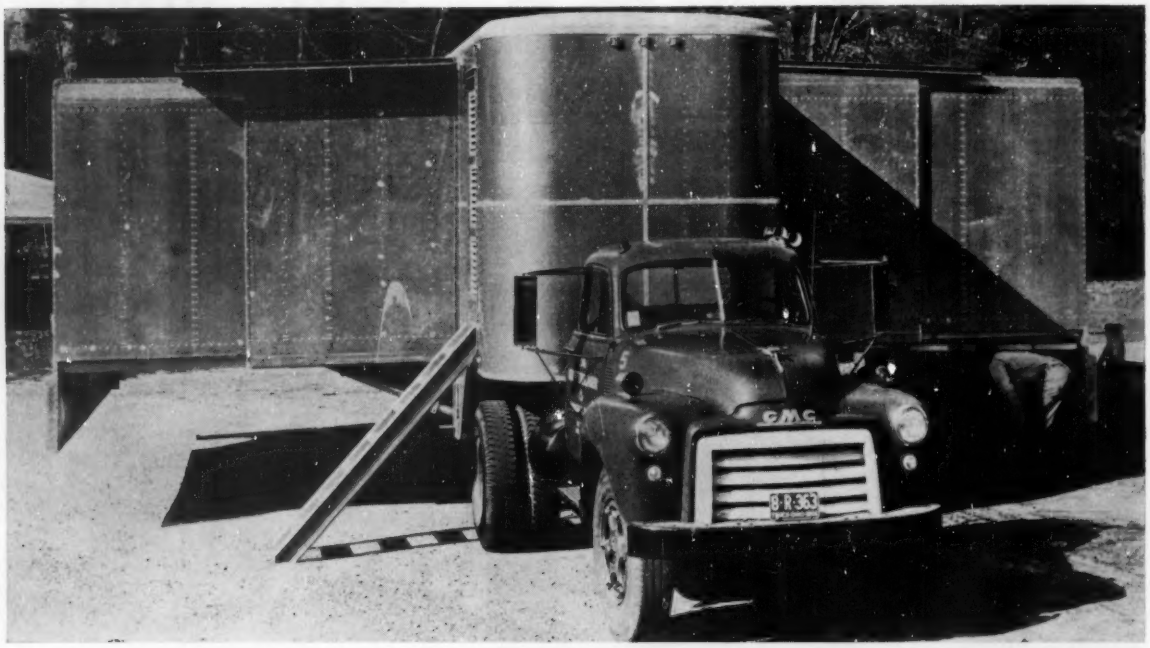
This new bearing is ready for you right now from stock in two standard sizes (illustrated). Other sizes will be available later.

For complete specifications, ask for Data Sheet No. K562 — write, call or wire Kaydon of Muskegon.

THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

All types of ball and roller bearings — 4" inside diameter to 124" outside diameter . . . Taper Roller • Roller Thrust • Roller Radial • Bi-Angular Roller • Spherical Roller • Needle Roller • Ball Radial • Ball Thrust Bearings



LARGEST EXPANDING TRAILER, made by Gerstenslager Co. with more than 12 tons of Alcoa aluminum, grows in 5 minutes to five times on-the-road size at the touch of a button. Sides telescope outward, while accordion-folded aluminum floors drop into place. Compacted for traveling, trailer is 35 ft long, 8 ft wide. Expanded, the interior is 30 ft long, 26 ft wide, 7½ ft high. Expansion is performed by hydraulic and chain drive mechanism powered by generator in forward end of trailer. Generator also powers lighting and air-conditioning systems. Builder sees the trailer used for industrial road shows in addition to military applications such as barracks, kitchens, communication centers, radar stations and machine shops.

(*Continued from Page* 14)

young engineers were not far behind. Dollar increases for the median engineer over the three-year period ranged from $1000 to $2000.

First glimpses of the new survey were reported on January 17 by Dr. Edward Peck at the EJC third general assembly. The complete report is expected to be released shortly.

Actual figures reported by Dr. Peck consisted of 10, 25, 50, 75 and 90 percentile curves for engineers in industry. These percentile curves can be considered to mark out evaluation levels; an engineer can spot his relative position on the curves. A correction for type of engineering, geographical location and other factors must be applied. All industries do not pay equally well. The salary survey included all types of engineers—mechanical, electrical, chemical, civil — and there are definite differences in salary scales. Engineers in government and education are not included; these fields generally lag behind the pay scales offered by industry.

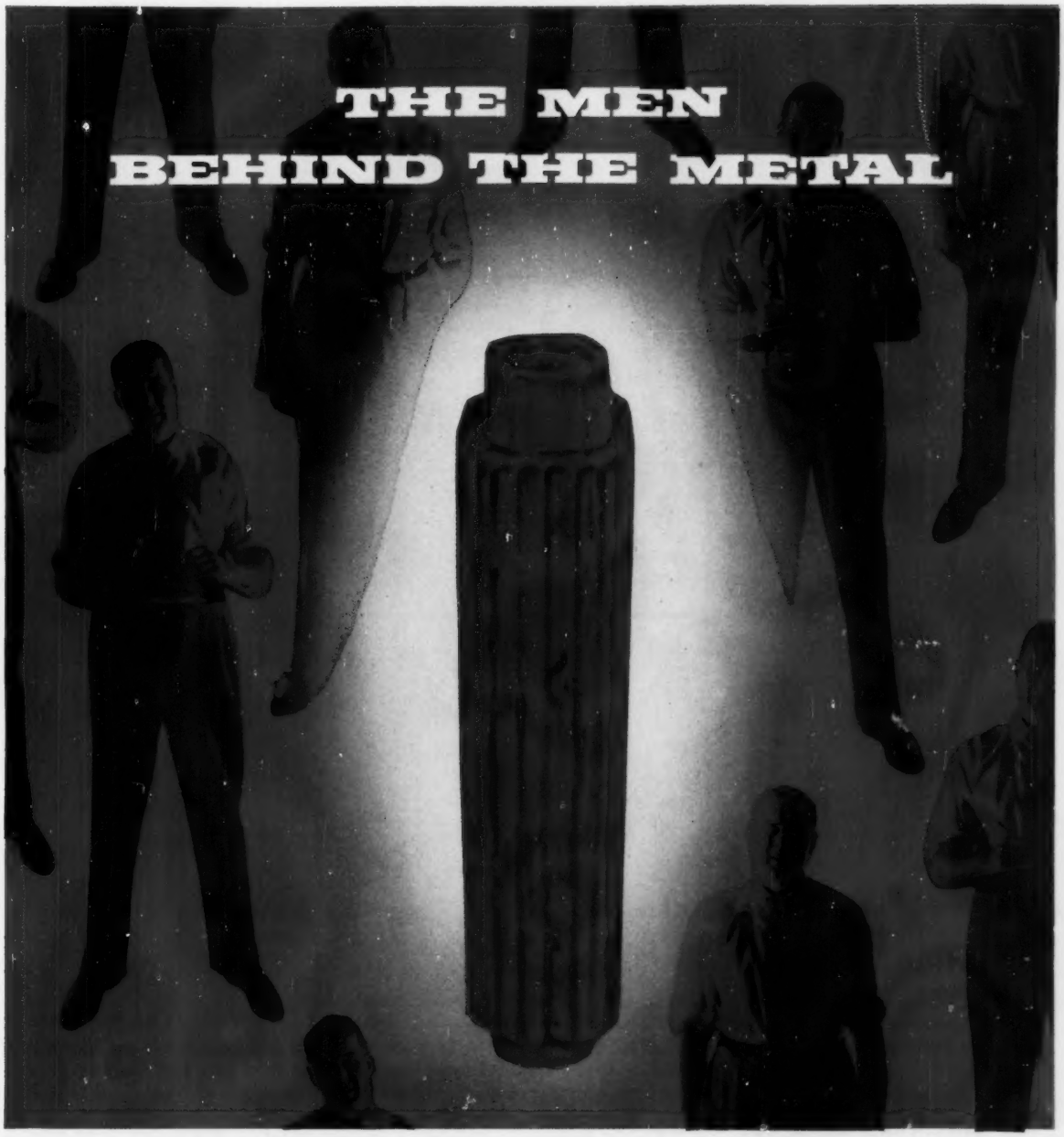
Spread between the high-pay and low-pay engineer remained about the same for about half the experience brackets. But in the 15 to 35-year experience bracket, the top men increased their lead. This may be a reflection of recent management increases in incentives for top-level and management engineers; this group remained static early on the period under pressure of salary increases for younger men.

It takes the median engineer about 7½ years to catch up in pay with carpenters or electricians, and about 10 years with plumbers or bricklayers, according to Dr. Peck. Total income for the median engineer over a 43-year career (ages 22 to 65) exceeds total income of a carpenter by approximately $80,000 and of a plumber by less than $50,000.

Small, One-Pound TV Camera Has Automatic Iris Control

CAMDEN, N. J.—A new pocket-size television camera has been developed by RCA for military airborne, mobile, and closed-circuit TV applications. The camera measures 1⅞ x 2⅜ x 4½ in. Its small size was made possible by transistors, special transistor circuitry, and a new ½-in. vidicon camera tube.

(*Continued on Page* 24)



The making of quality leaded alloy electric furnace steels is a highly scientific job. The planning, the constant study, the checking of minute details by skilled metallurgists, that go into the creation of one billet of leaded steel, represent one of the highest forms of industrial craftsmanship. At Copperweld, manufacturer of the most diversified line of lead treated and carbon steels, a staff of skilled metallurgists is constantly at work to insure Copperweld's leadership in the production of hot rolled blooms, bars and billets.

Our staff of field metallurgists is at your disposal to assist you in the selection of the best steel for any purpose. A call to a district office in any major city is all that is needed to bring this service to you.

COPPERWELD STEEL COMPANY • STEEL DIVISION • WARREN, OHIO
EXPORT: Copperweld Steel International Co., 225 Broadway, New York 7, N. Y.

Circle 414 on page 19

DO IT YOURSELF and SAVE SAVE SAVE

Paul W. Christman Jr.

VICE-PRESIDENT, THE CINCINNATI GEAR CO.

News Item: *Statistics show that hospital emergency wards do a rushing business on weekends — and not just after Saturday midnite, either, but* all *weekend long — patching split heads, wrenched backs, mashed thumbs, broken arms and chopped feet. All this "business" results from that modern phenomena, "do it yourself."*

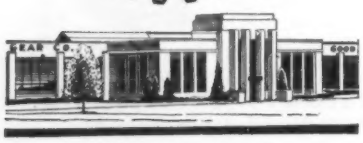
Any fool knows that "do it yourself" is the way to "Save - Save - Save," as the TV commercials say. But some of the *smarter* people have discovered that "do it yourself" isn't necessarily the bargain-counter proposition it's been made out to be — that the fun you get out of it (if any) generally costs *money* in the long run. These people are relearning a truth established years ago that the Division of Labor, or specialization, results in greater efficiency. This holds just as true in the production of industrial goods such as gears: the actual cost, hidden as well as apparent, of gears produced in a back shop or part-time department is bound to be greater than the ultimate cost of gears produced by an efficient, highly-specialized gear manufacturer like Cincinnati Gear. And combine the economic advantages that result from our efficient production and consistent top quality with the *ease-of-mind* that results from our traditionally top-notch *service*, and you'll understand why so many firms (firms who recognize "do it yourself" for what it is) depend on us year after year for all their custom gear requirements.

THE CINCINNATI GEAR CO.

CINCINNATI 27, OHIO

Fifty Years of *"Gears—Good Gears Only"*

CINTI®



Circle 415 on page 19

Engineering News Roundup

(*Continued from Page* 22)

The miniature camera, designated JTV-1, weighs less than 1 lb. Despite its size, it surpasses standard vidicon-type industrial TV cameras in sensitivity. Used with an F-1.9 lens, it requires only 10 foot-candles of scene illumination for clear pictures.

The camera incorporates numerous design and performance features for maximum flexibilty and operating convenience:

1. It can be operated in the palm of the hand, used with an attachable pistol-grip handle, bolted to wall or floor, or mounted on a tripod.

2. It is the first TV camera of its type to incorporate a photoelectric iris control, which automatically activates specific camera circuits to compensate for changing light levels. The photoelectric iris control enables the camera to accommodate changes in the order of 100 to 1 in scene lighting.

3. Designed for maximum power economy, the camera system operates from a 115-v, 60-cycle ac source, and draws less than 350 w. Camera dissipation is only 3 w.

4. Made rugged for military airborne, mobile, and field requirements, the pocket-size camera has a high level of resistance to shock and vibration. For unusual shock and vibration conditions, the camera design permits encasing of the complete internal construction in standard potting compounds.

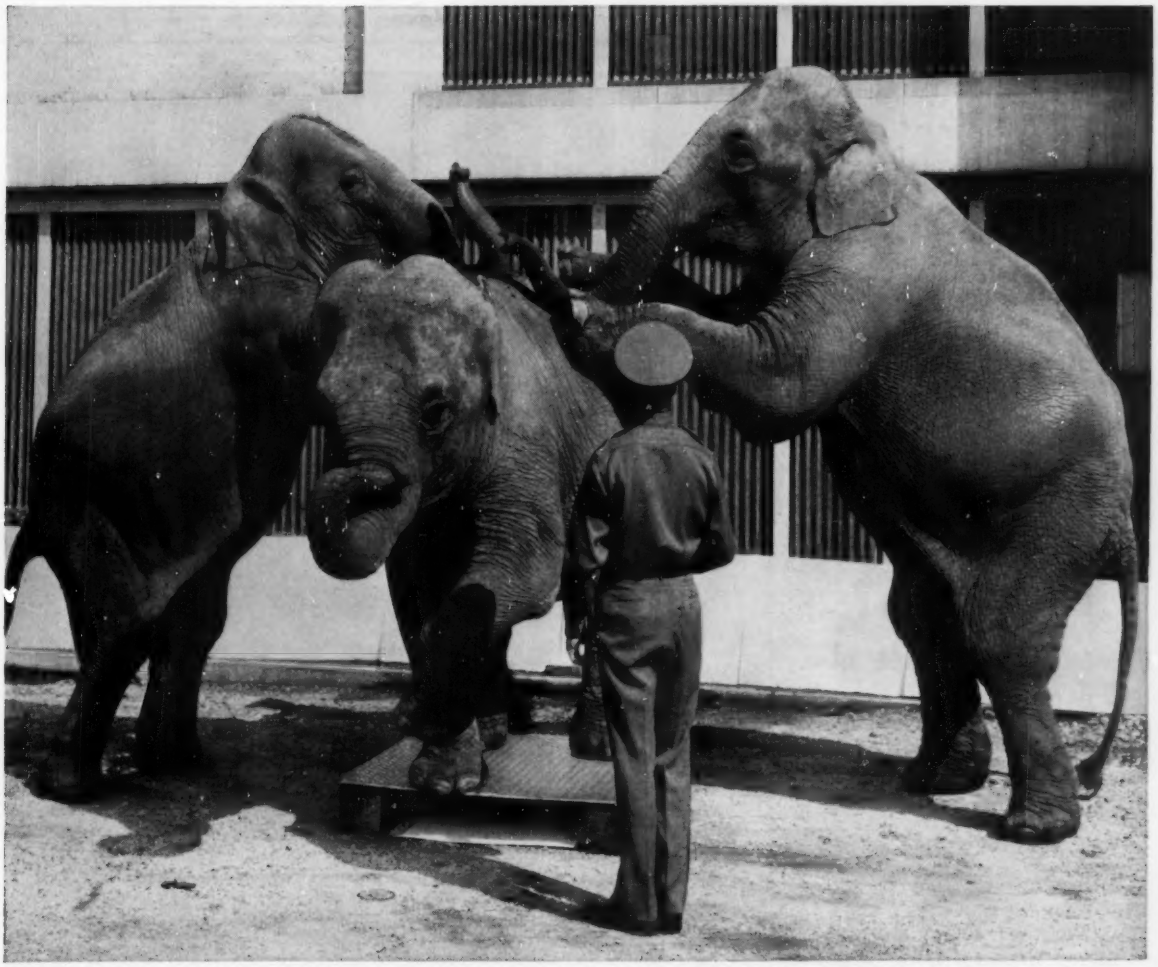
5. Featuring design and operating simplicity, the camera can be operated by nontechnical personnel. Once optical and electrical focus are fixed for a specific application, it rarely requires control adjustments.

Official U.S. Navy Photograph

FIRST HELICOPTER CARRIER, *USS Thetis Bay,* is a key vehicle in new Marine Corps amphibious operations. The Corps will experiment with vertical envelopment operations using helicopters flown from the *Thetis Bay.* The ship was converted from a WW II escort carrier to accommodate 20 HRS-type helicopters and half a Marine battalion in addition to its normal crew of 700 officers and men. Forward section of the hangar houses troops and helicopter spare parts. Helicopters are parked in the rest of the hangar and on the flight deck. A new elevator for the helicopters can handle large models still under development. Another new elevator expedites delivery of Marine ammunition and equipment to the flight deck. Island structure was modified to improve combined air-sea-land control.

Human Engineering to Gain Emphasis as Automation Grows

COLUMBUS, O.—As automation is extended, the importance of human engineering will grow correspondingly. Automation places large quantities of production capacity under the control of one operator. For this reason, operator error must be minimized, and this is one of the major functions of human engineering. These were the recent comments of Dr. Richard S. Laymon and Charlotte A. Christner, human engineering specialists at Battelle Memorial In-



2-TON BABIES PROVE 4-WAY'S STRUCTURAL STRENGTH

These frolicsome 2-ton circus babies demonstrate the ability of Inland 4-WAY Safety Plate to support tremendous weights. Because of 4-WAY's rugged strength, this 4′ x 4′ plate bears up under 4,000 pounds of pudgy pachyderm without a hint of strain.

The extreme structural strength of Inland 4-WAY Safety Plate is an important factor in plant safety. 4-WAY is not just another flooring surface material, but a steel plate that can be used as a structural member.

Strength, however, is only one of the advantages that 4-WAY offers. Its **slip-resistance, durability, attractive appearance, ease of application, fire resistance, ease of fabrication and cleanability** provide you with a combination of features unequalled by any other materials. Where can *you* use Inland 4-WAY Safety Plate? There are dozens of places in every plant where it can pay off in man hours saved . . . in providing safer, cleaner surfaces . . . in boosting general efficiency. For helpful suggestions and useful information, write to Dick Prendergast, Room 1262.

INLAND 4-WAY® SAFETY PLATE

INLAND STEEL COMPANY

38 South Dearborn Street • Chicago 3, Illinois

Sales Offices: Chicago • Milwaukee • St. Paul • Davenport St. Louis • Kansas City • Indianapolis • Detroit • New York

Circle 416 on page 19

Designing for High Temp?

Designing for Low Temp?

You Need the Special Advantages of Engineered Lubricants from ANDEROL

The products you design can be used at any temperature without change of lubrication . . . if your designs include a specially engineered Anderol Lubricant. Call the Lehigh Lubrication Specialist while your product is still in the design stage. Regardless of volume or requirements, Lehigh will engineer a special Anderol Lubricant to do the job.

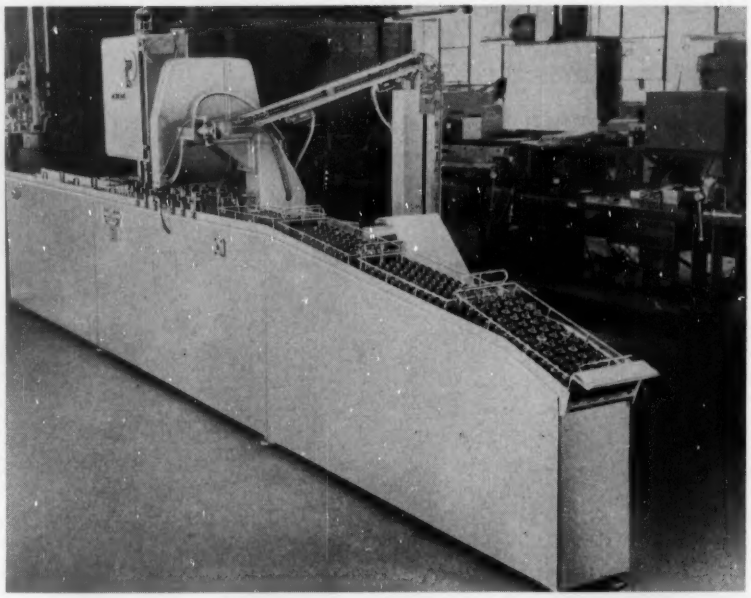
WRITE TODAY:

For complete data and government specifications. Our laboratories are at your service.

Write to Dept. 17

ANDEROL
ENGINEERED LUBRICANTS
Lehigh Chemical Company
CHESTERTOWN, MARYLAND

Circle 417 on page 19



HIGH-SPEED AUTOMATIC BASKETING method for automated or semi-automated production lines has been developed by the Gear-O-Mation Div. of Michigan Tool Co. Parts can be loaded at the rate of 3000 pieces per hour. The parts are fed to a dropping mechanism through an enclosed track. They roll down the track and are guided and tipped through a curved, channeled fixture and held positively at the bottom end. Release into baskets from this point is actuated by automatic indexing of the basket. Parts are dropped onto upright basket prongs a row at a time. Double or triple dwell of the indexing can be provided for stacking two or three gears.

stitute.

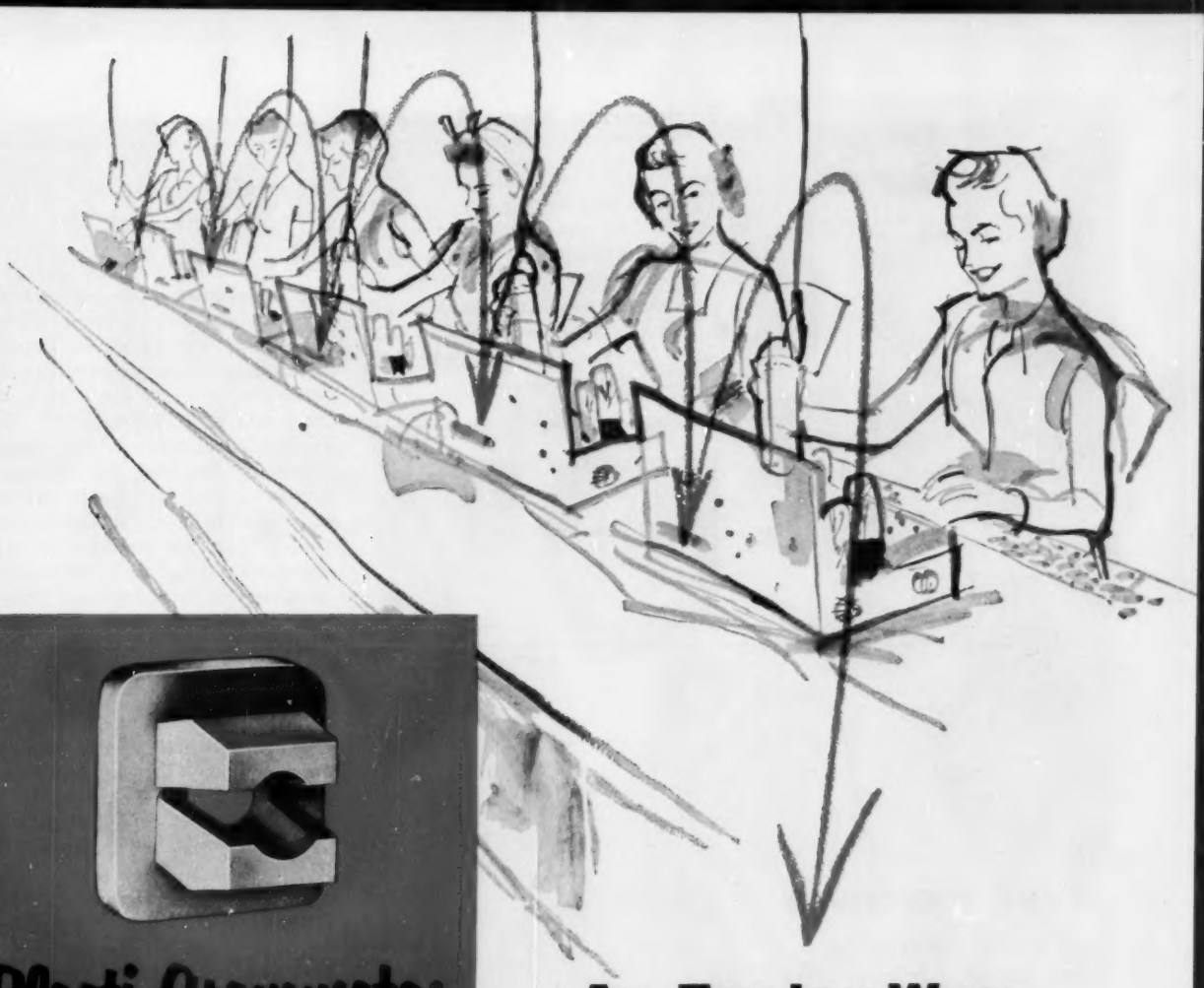
Human engineering, they say, is primarily a methodology of research to match the design of machines to the capabilities of the men who operate them. The machines can be simple hand tools or complex machine systems like automobiles and jet bombers.

The Battelle specialists noted three ways in which human engineering might play a part in the development of automation. First, human engineering can be employed to produce machine designs that minimize the probability of human errors. Second, it can provide recommendations as to which production tasks should be allocated to machines and which to humans. Third, human engineering may be used to decrease service and repair time on automated production lines. The equipment should be designed with the human engineering requirements for maintenance in mind. Among these considerations are accessibility and identification of parts, and the capabilities and limitations of the men who will do the maintenance.

Both our individual and our collective welfare can be improved, say Laymon and Christner, by applying human engineering principles to remove the hazards of man-machine situations. In the home there are many sources of costly and painful accidents. Still other situations exist in public places and in industry. Color coding of unsafe areas and the use of electronic safety controls on machines are two possible remedies.

The Battelle specialists believe that human engineers can help to reduce the suffering and waste caused by automobile accidents.

Research could be applied to many aspects of the problem. For instance, highway signaling systems could be redesigned to meet the requirements of human visual capability and to make full allowances for human reaction times and for the speeds currently in

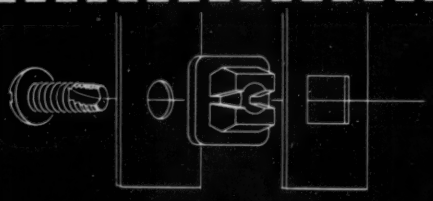


Plasti-Grommets®

Self-Retaining Blind Screw Receptacles

- non-corrosive
- non-conductive
- vibration-resistant
- does not chip or craze porcelain
- available in any color

35 sizes stocked



. . .An Easier Way to Speed Production

. . . and cut assembly costs, too! Plasti-Grommets snap into a prepared hole at the touch of a finger . . . replace other costly retained threaded receptacles, tapped holes or retained nuts. Locked in place by a thread-cutting screw, Plasti-Grommets provide a firm, durable, vibration-resistant fastener.

Developed at the Fastex creative engineering labs, Plasti-Grommets are a typical example of the simplification possible in multi-part assembly operations. Fastex volume production of metal and plastic components—on specialized manufacturing equipment—increases the economies gained through Fastex engineering ingenuity. These savings are being realized today in nearly every mass-production industry.

Test Plasti-Grommets® . . . *send for informative brochure and free packet of these remarkable nylon blind screw receptacles . . . actually test them . . . see how they can reduce your costs!*

FASTEX

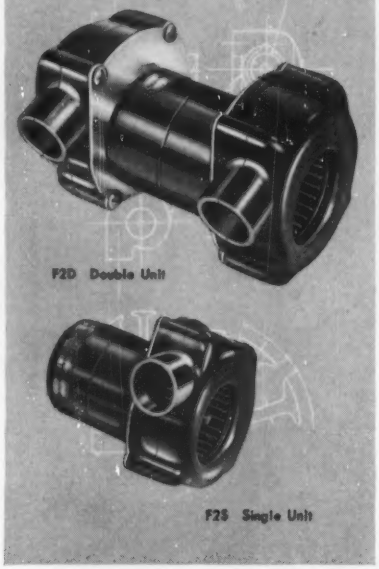
itw

A DIVISION OF ILLINOIS TOOL WORKS

195 Algonquin Road, Des Plaines, Illinois
In Canada: SHAKEPROOF-FASTEX,
Division of Canada Illinois Tools Ltd., Toronto, Ontario

Circle 418 on page 19

PUT HEINZE IN YOUR DESIGNS



TYPE F BLOWER

quiet operation for small air currents

Low in wattage, light in weight, neat in appearance, Type F Blowers are available as single or double units. Supplied with Type F 2-pole shaded pole induction motor. 15 watts, 115V AC, 60 cycle operation. Single unit has load speed of 3100 rpm, 10 cfm. Double unit operates at 3000 rpm, 20 cfm. Durable bakelite housing.

Ideal for any application requiring small current of air and quiet operation — cooling electronic tubes in transmitters, induction heaters, diathermy equipment; for advertising displays, etc.

Heinze blowers are also designed to your exact specifications. Write Dept.D for catalog.

HEINZE ELECTRIC COMPANY
685 Lawrence St., Lowell, Mass.

SUB-FRACTIONAL HORSEPOWER MOTORS AND BLOWERS

Circle 419 on page 19

practice on the road.

Human engineering may also be applied in establishing reliable product inspection systems, evaluating the effect of product change on product sales, and in creating working environments with optimum lighting, seating, tool, and supply arrangements.

SUNDIAL FOR DARK DAYS is this electric model made by GE-Telechron. Under a transparent plastic dome, time is indicated by shadows cast onto the dial. An electric movement in the brass cylinder moves the "hand." Garden-size model is 4 ft high; indoor version 15 in. Telechron does not indicate what pithy legend might circle the dial, as on the "obsolete" type, nor if an alarm model is to be made.

Society of Automotive Engineers has announced the election of W. Paul Eddy as president for 1957. Mr. Eddy, a member of the society since 1947, was vice president in 1955 and is a former chairman of the Southern New England Section. He has served on various SAE national committees and has delivered several technical papers at the society's annual meetings. Mr. Eddy is chief of engineering operations at the Pratt & Whitney Aircraft Div. of United Aircraft Corp., West Hartford, Conn.

Engineering Graduates Seek Stimulating Jobs

NEW YORK, N. Y.—Jobs that present stimulating problems and offer the possibility of increased responsibility are sought by today's electrical engineering graduates, according to a paper given by D. S. Babb and M. S. Helm of the University of Illinois at the recent American Institute of Electrical Engineers meeting. An evaluation of a student panel discussion revealed that the majority of students are not unduly influenced by promises of bonuses and fringe benefits from would-be employers. They are, in fact, skeptical of bonus offers and high starting salaries without job security.

Security is not thought of by the student as merely being retained on a company payroll, but is regarded in terms of chances to advance according to ability and to develop professionally and creatively.

Remarks and attitudes of the students also suggested two types of publicity needed about engineering, according to Messrs. Babb and Helm. They recommend quite general and "somewhat glamorous" publicity directed at elementary and secondary school students to stimulate a positive interest in engineering, and, for college students, information about engineering problems in various types of companies employing engineers.

Most Powerful Locomotive To Be Gas-Turbine Powered

NEW YORK, N. Y.—An impending development in the application of the gas turbine is a gas-turbine-electric locomotive faster and more powerful than any locomotive now in use. This was reported by F. D. Gowans and A. H. Morey of GE in a recent AIEE paper.

Locomotives using gas-turbine power plants in some form are only at the threshold of their development. Most of the work to date has been with the simplest form of this prime mover. This form is competitive, where the

There's been a revolution going on under the surface!

Sleeve bearings have *looked* much the same for 50 years. But there the resemblance ends. Take this modern bearing, for example. It has a steel back, a sintered layer of copper-lead alloy, a brass barrier plate and a lead-tin overplate. It's a far cry from the simple babbitt bearings of the past—but so are the load, speed and temperature complications facing today's engine builders. Tomorrow there will be demands for new types of bearings . . . and designers and manufacturers will team up with Federal-Mogul Engineering to create and produce them. *Your* inquiry is invited now.

FEDERAL Mogul
SINCE 1899

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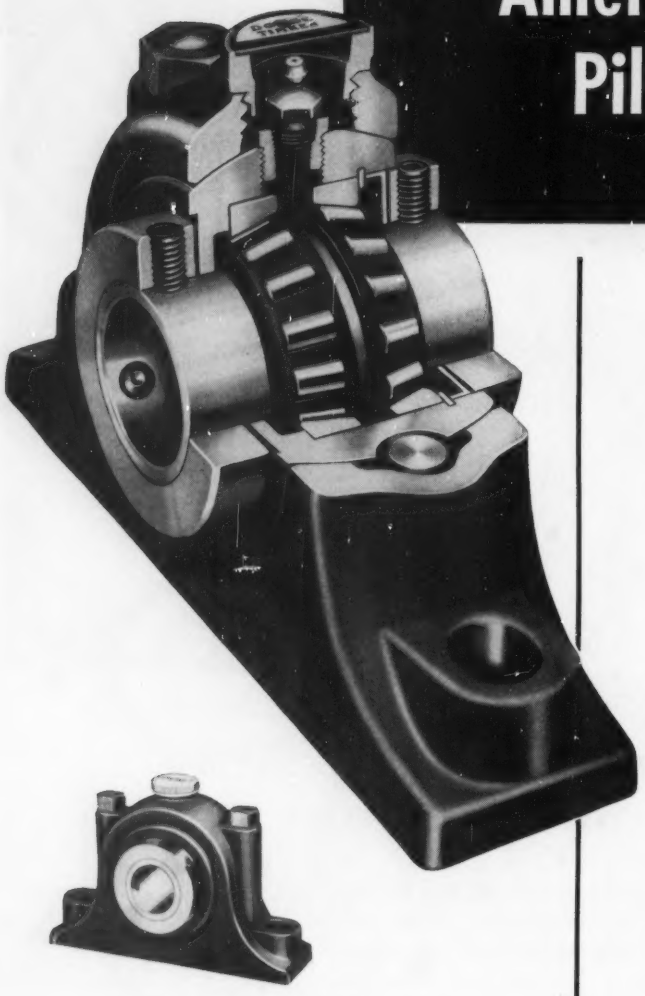
FEDERAL-MOGUL-BOWER BEARINGS, INC., 11045 SHOEMAKER, DETROIT 13, MICHIGAN

RESEARCH • DESIGN • METALLURGY • PRECISION MANUFACTURING

Circle 420 on page 19

AVAILABLE IN FIVE TYPES
FOR ALL KINDS OF SERVICE

DODGE-TIMKEN
America's Quality Pillow Block



- COMPLETELY ASSEMBLED
- FACTORY ADJUSTED
- PRE-LUBRICATED

Call the Transmissioneer, your local Dodge Distributor. Factory-trained by Dodge, he can give you valuable assistance on new, cost-saving methods. Look for his name under "Power Transmission Machinery" in your classified telephone directory, or write us.

DODGE-TIMKEN Bearings are adjusted, lubricated and sealed at the factory. Labrynth seals effectively retain the lubricant and prevent the entrance of dust and dirt. The inbuilt precision of Dodge-Timken Bearings is protected both on and off the shaft. They are delivered fully assembled, ready to mount.

Where service conditions are toughest Dodge-Timken Bearings prove their quality decisively. For superior performance, dependability and long life they have won their reputation throughout industry as America's quality pillow blocks.

To meet varying service requirements Dodge-Timken Pillow Blocks are available in five types—the type E . . Double Interlock (illustrated) . . Type C . . Special Duty . . . and All-Steel. Available in a range of shaft sizes from 1-3/16" to 10".

Call your Transmissioneer; or write for Bulletin A638 giving load ratings, dimensions and other data on Dodge-Timken Roller Bearings.

DODGE MANUFACTURING CORPORATION
3300 Union Street, Mishawaka, Indiana

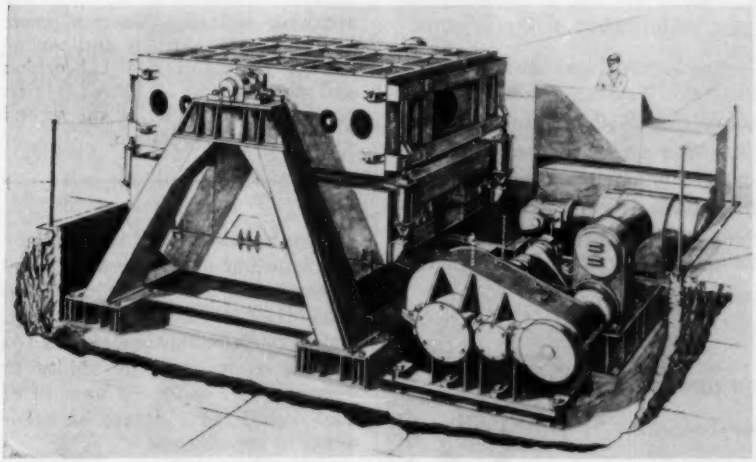
DODGE
of Mishawaka, Ind.

Circle 421 on page 19

NEW THUNDERBIRD has grown 5½ in. longer than the 1956 model. This extra length, combined with a raised deck top, provides a larger luggage compartment. The spare tire has moved back inside the luggage compartment, which redistributes weight and improves handling. Rear quarter panels are higher, and the upper panel edges slant outward. Larger bumpers both front and rear contain parking lights and exhaust ports. Thunderbirds are available with engines rated 212 to 270 hp. Low-pressure, wide-tread tires are mounted on 14-in. diameter wheels. A new radio in the car automatically adjusts to maintain the proper listening level regardless of road speed.

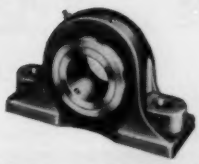
proper fuels are available, with other locomotive prime movers.

The new locomotive under construction will be rated 8500 hp at 6000 ft altitude and 90 F. Its capability is indicated by the fact that it will have 20 hp per ton of weight on drivers as compared to 16 for the gas-turbine-electric locomotives now in service on the Union Pacific Railroad, and 14 for diesel-electric-freight locomotives. The



SHAKEDOWN FOR AIRCRAFT COMPONENTS will be performed on this slosh and vibration table designed by Century Engineers Inc. for Wright Air Development Center. The unit will be used for environmental testing of aircraft fuel cells and tanks. Platform to receive test specimen is 8 ft wide, 10 ft long, mounted on four air cylinders which isolate vibrations from the reaction block. Vibration driving force is produced by four eccentric-mass force generators. Each capable of 60,000 lb peak force, the generators will be the largest made. Specimens up to 20,000 lb can be vibrated at 20 to 50 cps with peak acceleration of 7.7*g* and sloshed at 10 to 20 cpm at double amplitudes of 16 to 30 degrees.

DODGE PRODUCTS you should know



SC and SCM
BALL BEARING
PILLOW BLOCKS

TAPER-LOCK
ALL STEEL
CONVEYOR PULLEYS

DODGE TAKE-UPS

DODGE BULLETINS YOU SHOULD HAVE

1 ROLLING BEARINGS. Load ratings, dimensions and other data on Dodge-Timken and SC and SCM Ball Bearings. Bulletin A638.

1 TAPER-LOCK STEEL CONVEYOR PULLEYS. Construction details, sizes, dimensions. Bulletin D56.

1 DODGE TAKE-UPS. Roller Bearing, Ball Bearing, Babbitted. Bulletin D56.

Write for your copies.

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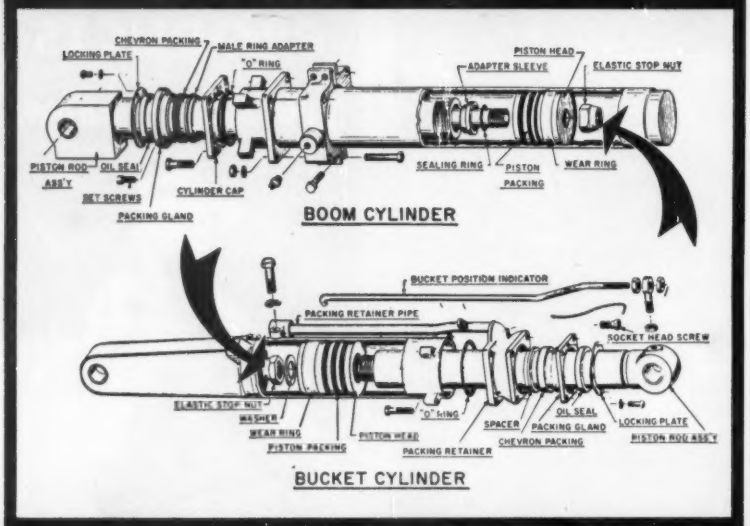
3300 Union Street • Mishawaka, Indiana

DODGE
of Mishawaka, Ind.

Circle 422 on page 19

FASTENER PROBLEM



How to retain hydraulic piston rods better–and cheaper

The Frank G. Hough Co. were using castellated nuts and cotter pins to retain the piston rods in hydraulic cylinders (shown above) installed on their earth moving equipment. There were four nuts per cylinder and two cylinders per machine. Cross-drilling was required for the cotter pins used to lock the slotted nuts. This added to the cost of the fastening, and insertion of the cotter pin was one more labor operation. The problem was to reduce costs and, if possible, improve the performance of the fastener.

A standard nylon insert Elastic Stop® nut was tested and ultimately approved. Shop trials showed they cut costs on the "Payloader" because they are simpler and less expensive to assemble–and final adjustment is far more precise than was ever possible with cotter pins. Two years of field testing gave convincing proof that stop nuts held fast under vibration and stress. The nylon locking insert is almost impervious to wear and guarantees extended reusability–making cylinder maintenance simple and economical . . . no matter how frequent it may be. Elastic Stop nuts are now in general use on all "Payloader" equipment.

MAIL COUPON FOR DESIGN INFORMATION

ESNA TRADE MARK

Dept. N17-24 Elastic Stop Nut Corporation of America
2330 Vauxhall Road, Union, New Jersey

Please send me the following free fastener information:

☐ Elastic Stop Nut bulletin

☐ Rollpin Catalog

☐ Here is a drawing of our product. What self-locking fastener do you suggest?

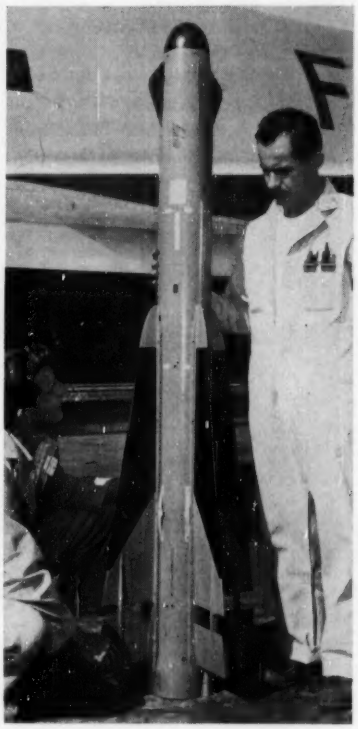
Name_____ Title_____

Firm_____

Street_____

City_____ Zone____ State_____

News Roundup



FALCON, INDEED, is this new version of the air-to-air missile designated GAR-1D. Radar-guided, the Falcon is launched from jet interceptors, climbs higher than any similar weapon as well as the interceptors themselves, outmaneuvers attacking aircraft. Falcon is made by Hughes Aircraft Co. and carried by the Northrop F-89H Scorpion and the Convair F-102A. It first bowed to the public at the second Eisenhower inauguration.

locomotive consists of an auxiliary and a turbine-generator unit. Fuel is carried in a tender coupled behind the turbine-generator unit. This gives constant weight on the drivers as well as the ability to carry several times the amount of fuel considered standard on other types of locomotives.

The turbines in these locomotives will have a lower fuel rate per horsepower than previous units as the result of improved component efficiency and larger size. The combination of added range of operation without refueling and lower rate per horsepower will increase mileage and lower operating expenses.

News Roundup

Graphical symbols for fluid power diagrams are the subject of a proposed American Standard, ASA Y32, currently being distributed for criticism and comment. The standard shows basic symbols, describes principles on which the symbols are based, and illustrates representative composite symbols. Emphasizing function and method of operation of components, graphical symbols are considered to meet circuit diagram requirements for design, fabrication, sales and service. Free copies are available from Frank Philippbar, Standards Dept., ASME, 29 W. 39th St., New York 18, N. Y.

Meetings

AND EXPOSITIONS

March 6-8—

Pressed Metal Institute. Annual Spring Technical Meeting to be held at Hotel Carter, Cleveland. Further information is available from institute headquarters, 3673 Lee Rd., Cleveland 20, O.

March 7—

Fourteenth Annual Machine Design Conference, sponsored by the Cleveland Engineering Society. Conference will be held at society headquarters, 2136 E. 19th St., Cleveland, O. Further information is available from Joseph H. Gepfert, Reeves Pulley Co., 6408 Euclid Ave., Cleveland, O.

March 11-14—

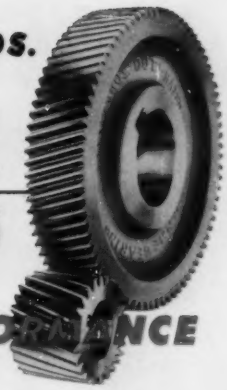
1957 Nuclear Congress and International Atomic Exposition, to be held at Convention Hall, Philadelphia. This second nuclear engineering and science conference, sponsored by 20 technical societies, is co-ordinated by the Engineers Joint Council. Further information can be obtained from the Council, 29 W. 39th St., New York 18, N. Y.

March 11-15—

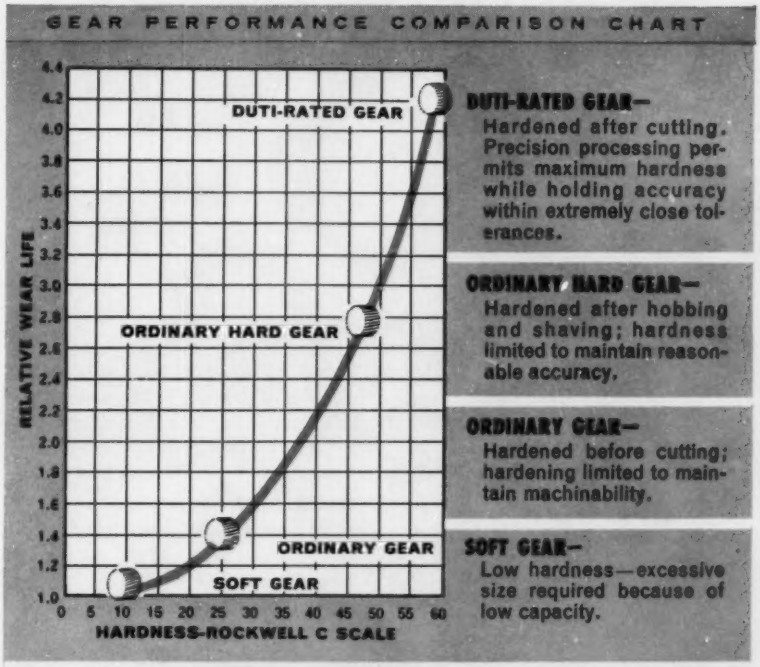
National Association of Corrosion Engineers. Thirteenth Annual Conference and Exhibition to

HERE'S WHY FOOTE BROS.

Duti-Rated LIFETIME GEARING



GIVES BETTER PERFORMANCE ...LONGER LIFE


GEAR PERFORMANCE COMPARISON CHART
RELATIVE WEAR LIFE
HARDNESS-ROCKWELL C SCALE
DUTI-RATED GEAR
ORDINARY HARD GEAR
ORDINARY GEAR
SOFT GEAR
DUTI-RATED GEAR— Hardened after cutting. Precision processing permits maximum hardness while holding accuracy within extremely close tolerances.
ORDINARY HARD GEAR— Hardened after hobbing and shaving; hardness limited to maintain reasonable accuracy.
ORDINARY GEAR— Hardened before cutting; hardening limited to maintain machinability.
SOFT GEAR— Low hardness—excessive size required because of low capacity.

Write for DUTI-RATED Gear and LINE-O-POWER Catalogs.
See how you can get more for your drive dollar.

this trademark stands for the finest industrial gearing made

T. M. REG. U. S. PAT OFF

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Better Power Transmission Through Better Gears

FOOTE BROS. GEAR AND MACHINE CORPORATION
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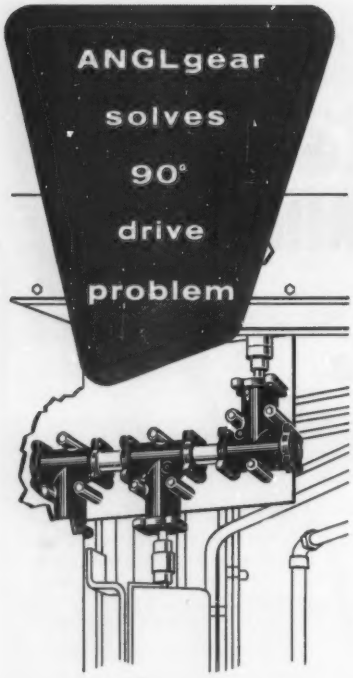


Simplified drawing, based on actual photo, shows ANGLgear installation on Cleveland Punch and Shear Works Co. power press. Compact, universal-mounting ANGLgears provide safe, positive 90° drive for press limit-control switches.

Cleveland Punch and Shear Works Co. engineers selected ANGLgears to actuate limit switches on Cleveland punch presses for these reasons:

First, it was essential to have direct-connected, lagfree control of press stroke, to eliminate any chance of over-runs and consequent injury to operators and expensive dies. Second, the necessary right-angle drives had to be extremely compact, easy to install, and virtually maintenance-free.

ANGLgear met these specifications and Cleveland has continued to purchase the unit.

If you have a 90° power take-off problem, investigate ANGLgear. Completely enclosed, permanently lubricated ANGLgears are available immediately from stock in 1 to 5 hp ratings, with 2 or 3-way shafting, and 1:1 or 2:1 gearing.

See our literature in Sweet's product design file; then contact your local distributor or write direct.

AIRBORNE®

AIRBORNE ACCESSORIES CORPORATION
HILLSIDE 5, NEW JERSEY

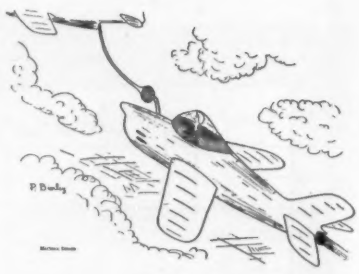
Circle 425 on page 19

Engineering News Roundup

be held at Kiel Auditorium, St. Louis. Additional information can be obtained from association headquarters, 1061 M & M Bldg., Houston 2, Tex.

March 13-15—

National Fluid Power Association. Spring Meeting to be held at Hollywood Beach Hotel, Hollywood, Fla. Further information can be obtained from association headquarters, 1618 Orrington Ave., Evanston, Ill.



"Whoa!"

March 18-19—

Steel Founders' Society of America. Annual Meeting to be held at the Drake Hotel, Chicago. Further information is available from society headquarters, 606 Terminal Tower, Cleveland 13, O.

March 18-20—

American Society of Mechanical Engineers. Gas Turbine Power Conference to be held at the Sheraton-Cadillac Hotel, Detroit. Further information can be obtained from society headquarters, 29 W. 39th St., New York 18, N. Y.

March 18-21—

Institute of Radio Engineers. National Convention to be held at the Waldorf Astoria Hotel and the Coliseum, New York. Additional information can be obtained from institute headquarters, 1 E. 79th St., New York 21, N. Y.

March 18-21—

Society of the Plastics Industry Inc. Annual National Conference and Pacific Coast Plastics Exposition to be held at the Hotel Biltmore, Los Angeles. Further information can be obtained from society headquarters, 250 Park Ave., New York 17, N. Y.

March 18-21—

Military Automation Exposition to be held at the Trade Show Bldg., New York. Further information is available from Richard Rimbach Associates, 845 Ridge Ave., Pittsburgh 12, Pa.

March 20-22—

Society of Automotive Engineers Inc. Production Meeting and Forum to be held at Hotel Statler, Buffalo, N. Y. Further information is available from society headquarters, 29 W. 39th St., New York 18, N. Y.

March 25-29—

American Society for Metals. Biennial Technical Meeting to be held at the Ambassador Hotel, Los Angeles. Additional information is available from society headquarters, 7301 Euclid Ave., Cleveland 3, O.

April 2-5—

Society of Automotive Engineers Inc. Aeronautic Meeting and Production Forum and Aircraft Engineering Display to be held at the Hotel Commodore, New York. Further information is available from society headquarters, 29 W. 39th St., New York 18, N. Y.

April 8-10—

American Society of Mechanical Engineers. Spring Meeting to be held at the Hotel Dinkler-Tutwiler, Birmingham, Ala. Further information is available from society headquarters, 29 W. 39th St., New York 18, N. Y.

April 8-11—

American Management Association. National Packaging Conference and Exposition to be held at the International Amphitheatre and the Palmer House, Chicago. Additional information can be obtained from association headquarters, 1515 Broadway, New York 36, N. Y.

GOLD-N-RING ... a new name and a new conception of CONTROL SWITCH design

HEAVY-DUTY

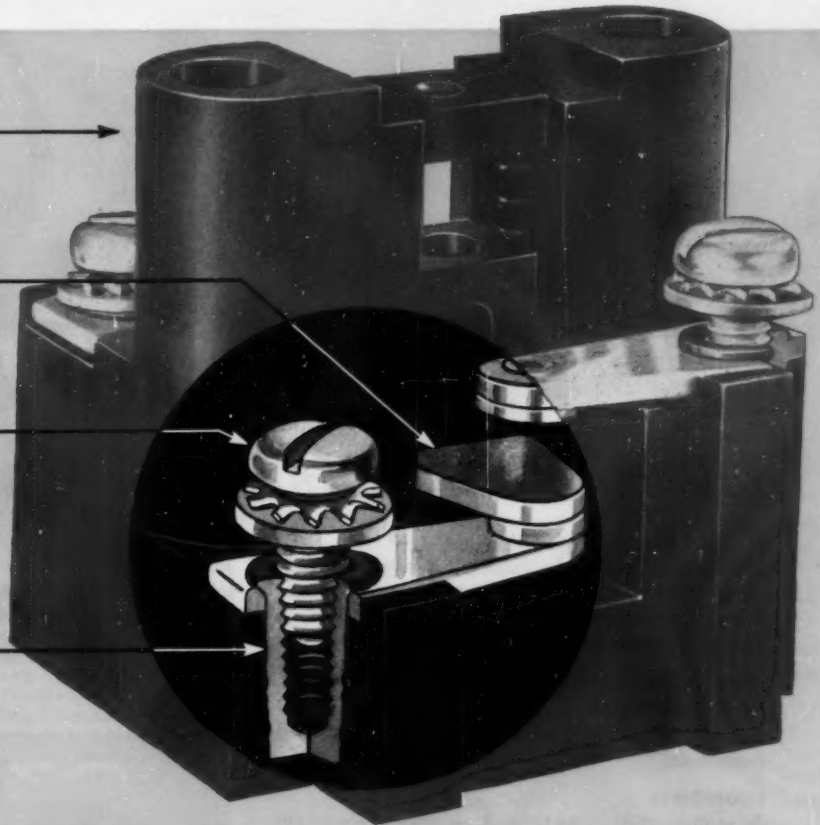
OIL-TIGHT—WATER-TIGHT—DUST-TIGHT

made by machine tool builders to machine tool specifications

A new name—GOLD-N-RING Sealtight Control Switch! A new conception—a control switch *designed and built BY a manufacturer of machine tools—FOR machine tool builders!*

A product of the same machine tool background responsible for Namco Solenoids and Snap-Lock Limit Switches, it gives designers a *package of greater electrical efficiency*—available from a single source, with a single source responsibility.

Shown here are only a few of many reasons why the GOLD-N-RING Control Switch makes it possible to match machine tool mechanical ruggedness with equally durable electrical efficiency.



1 **MAIN BLOCK** is unit-molded to assure alignment and simplify assembly.

2 **HEAVY-DUTY SILVER-ALLOY CONTACT POINTS** for maximum electrical capacity and long life.

3 **HEAVY-DUTY TERMINAL SCREWS**, with 3/8" thread contact, prevent stripping during installation; permanently secure wires for continuous trouble-free service.

4 **BRASS INSERTS MOLDED IN THE BLOCK** permanently hold stationary contacts. They also provide more thread support for the No. 8-32 terminal screws that are equipped with captive flat and lock type washers.

For complete details, send for Bulletin ECS-56. Better yet, ask for a representative to bring a switch for your examination.

ELECTRICAL MANUFACTURING DIVISION

National Acme

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Circle 426 on page 19

NEW

OZALID STREAMLINER 200

full-width whiteprinting for just $995.00!

Here's economical printmaking for every architectural office—*in full 42-inch widths!* Here's the brand-new Ozalid Streamliner 200—compact, low-cost table-model whiteprinter.

NEW CONVENIENCE
With Streamliner 200 in your office—you get prints whenever you need them—as soon as you need them.

ECONOMY!
In savings of drafting time alone, your Streamliner 200 quickly pays for itself. You make changes with *intermediates*—no costly re-drawings!

TOP QUALITY PRINTS, TOO
You get sharp, detailed prints—*in seconds.* Simple controls are easy to operate. Prints stack automatically. Compact design; only 22″ high, 27″ deep.

For all the facts on the Streamliner 200, call your local Ozalid representative. His number's in the phone book, or write: Ozalid, Dept. GG-2, Johnson City, N. Y.

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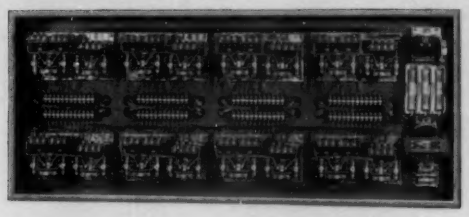
In Canada: Hughes Owens Company, Ltd., Montreal

Circle 427 on page 19

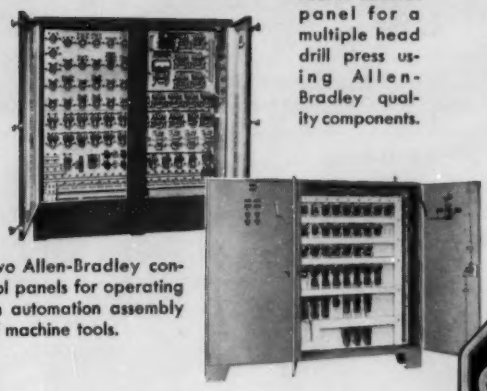
Circle 428 on page 19→

for trouble free operation—

let ALLEN-BRADLEY build your Special Control Panels



Motor control panel for a multiple head drill press using Allen-Bradley quality components.



Two Allen-Bradley control panels for operating an automation assembly of machine tools.

When the control panel furnished with your production machine carries the Allen-Bradley trademark of QUALITY, your customer's approval is assured! That is why so many leading machinery builders have standardized on Allen-Bradley controls. The "simple design" of all Allen-Bradley controls is your guarantee of trouble and maintenance free service.

No matter how complex your control requirements may be, as specialists in this field, Allen-Bradley's experience may be of valuable assistance to you. Call your nearest A-B office.

Allen-Bradley Co., 1316 S. Second St., Milwaukee 4, Wis.
In Canada—Allen-Bradley Canada Ltd., Galt, Ont.

ALLEN-BRADLEY

QUALITY

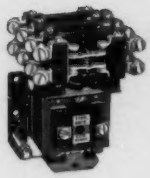
MOTOR CONTROL

A-B Quality

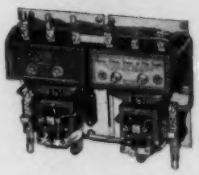
3-57-R

"we'll use ALLEN-BRADLEY Quality Motor Control ...it's trouble free!"

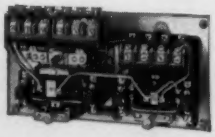
SPECIFY THESE RELIABLE MOTOR CONTROL UNITS



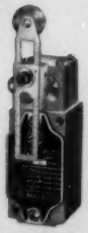
Bulletin 700
Universal Relay with
N.O.—N.C. Contacts



Bulletin 705 Size 2
Reversing Starter

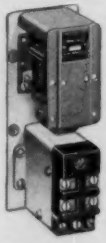


Bulletin 715 Two
Speed Consequent
Pole Starter



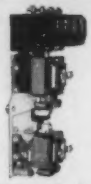
Bulletin 802T Adjustable
Lever Oiltight Limit
Switch

Bulletin 702 Three Pole
Size 2 Contactor



Bulletin 849 "On-Delay"
Pneumatic Timer

Bulletin 892
Handy Terminal
Blocks

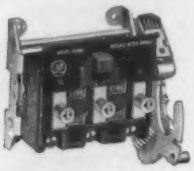


Bulletin 704, Mechanically
Held, Hum-free Relay

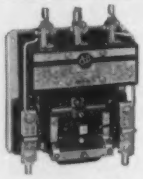
Bulletin 200
D-C Relay

Bulletin 350
Reversing Drum Switch

Bulletin 836
Pressure Control in
NEMA Type 4 Enclosure

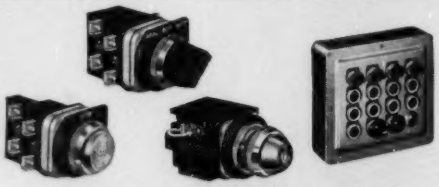


Bulletin 894
Visible Blade
Disconnect Switch



Bulletin 709
Size 4 Automatic
Starter

Bulletin 609
Three Phase
Manual Starter



Oiltight Push Button, Selector Switch, Press-to-Test
Pilot Light, and completely assembled Oiltight Station

Allen-Bradley *quality* components assure you millions of trouble free operations. The simple design, maintenance free, double break, silver alloy contacts, and rugged design features have made them the first choice among design engineers, contractors, and maintenance men. You just can't go wrong with this QUALITY line.

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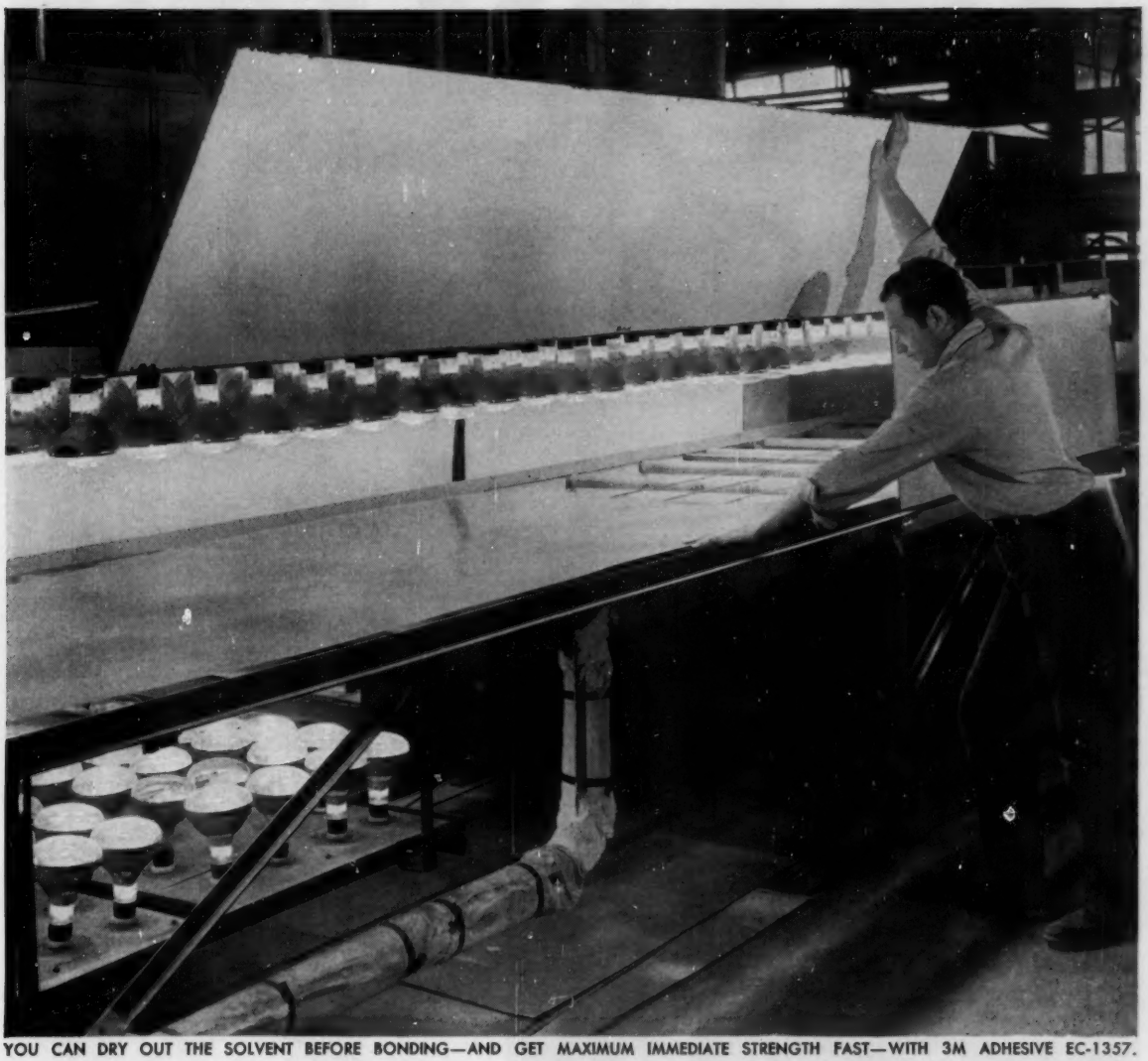
In Canada—Allen-Bradley Canada Ltd., Galt, Ont.

Send for your copy of the new 7th edition of the Allen-Bradley Handy Catalog

3-57-MR

Speed high-strength sandwich bonding by predrying 3M adhesive EC-1357



YOU CAN DRY OUT THE SOLVENT BEFORE BONDING—AND GET MAXIMUM IMMEDIATE STRENGTH FAST—WITH 3M ADHESIVE EC-1357.

Here's new speed in making light, rugged sandwich panels for non-load-bearing uses!

It's EC-1357. This specially formulated, fast adhesive from the laboratories of 3M gives you high bond strength *immediately!* With infrared ovens, you can dry the solvent out of EC-1357 before bonding. Heat absorption is fast, due to EC-1357's dark color. You eliminate unnecessary drying and storage time. You need no clamps or heated presses, just cold press or nip roller. What's more, this cold bond continues to cure at room temperatures—gains added strength with age.

On metal or paper honeycomb cores, EC-1357 builds up a fillet for bigger bonding area and strength. Use EC-1357 with glass foam cores, too.

SEE WHAT 3M ADHESIVES CAN DO FOR YOU! Consult 3M Research, contact your 3M Field Engineer or write on your company letterhead for information and free literature to: 3M, Dept. 102, 417 Piquette Ave., Detroit 2, Mich.

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MINNESOTA MINING AND MANUFACTURING COMPANY · ADHESIVES AND COATINGS DIVISION

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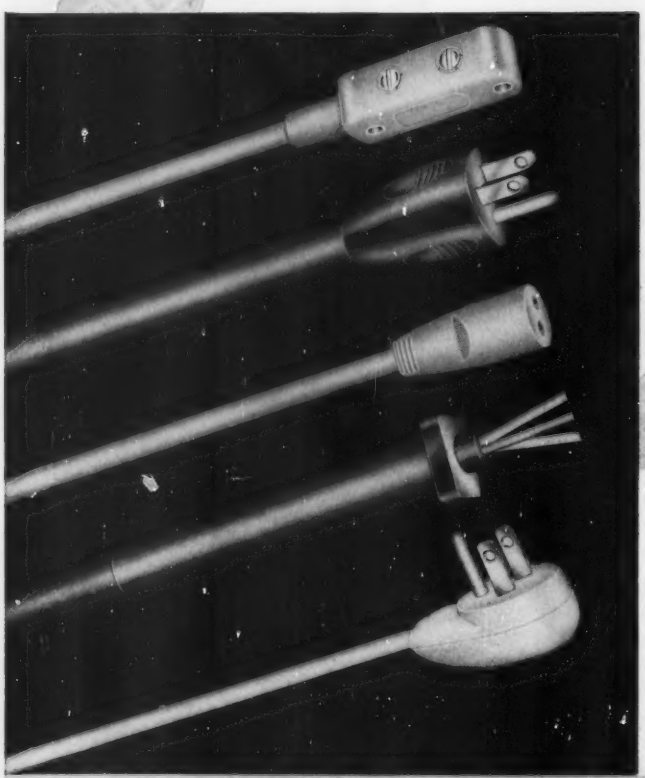
The difference in cost between "average" cord sets and superlative CORNISH Cord Sets is negligible — just peanuts. The difference in value to your equipment and appliances is very real and considerable. If you want your products to work better, LONGER — play it smart . . .



Cornish 'em...!

All Cord Sets available in **COLOR** to match your appliances, both in Rubber and in Plastic

Send us your specifications; consult us without obligation.

CORNISH

Custom **CORD SETS**

"Made by Engineers for Engineers"

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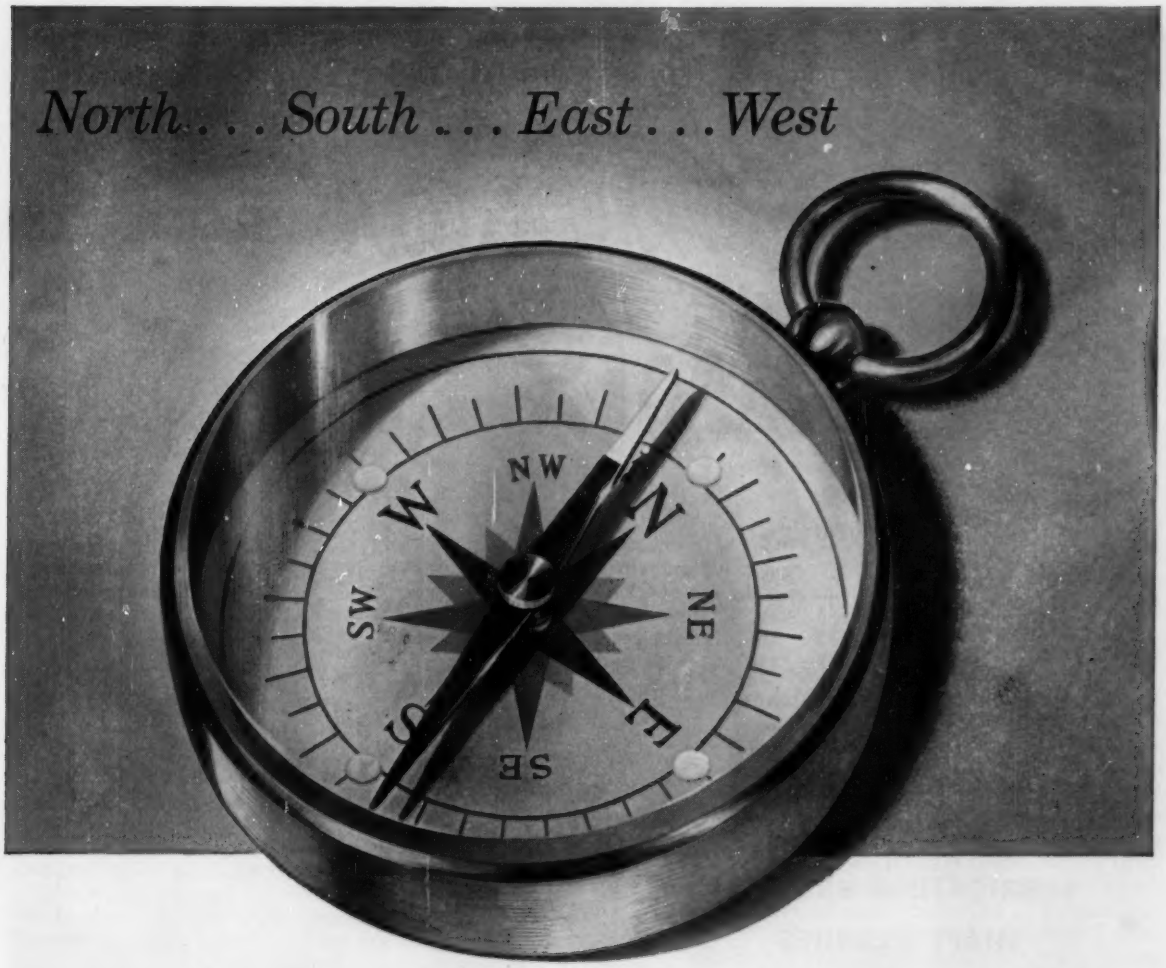
Creators and Manufacturers of CORDS AND CORD SETS FOR HOME, FARM AND INDUSTRY



The performance and the name are the same around the world

MACHINERY MANUFACTURERS:

The performance of Shell Alvania Grease enjoyed by your domestic customers is available abroad. And this same uniformity applies to

SHELL TURBO OIL—gives anti-wear lubrication for utility, industrial and marine turbines

SHELL TELLUS OIL—lubricant and control fluid for complex hydraulic systems, and a complete line of other

SHELL INDUSTRIAL LUBRICANTS

Shell Alvania Grease, used world-wide as a multi-purpose lubricant, has an outstanding performance record in solving many of the toughest anti-friction bearing grease problems. Ideal for wet, humid applications (inhibited to prevent water corrosion), it lubricates under water-wet conditions which normally spell trouble.

Alvania* Grease has the added advantage of remaining plastic in sub-zero weather and stable under sustaining high temperatures. This one grease successfully replaces dozens of special lubricants in plant after plant . . . reason enough for its universal popularity. For complete information, write Shell Oil Company, 50 West 50th St., New York 20, N. Y., or 100 Bush St., San Francisco 6, Calif.

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SHELL ALVANIA GREASE

A TRULY MULTI-PURPOSE LUBRICANT

SHELL

Circle 431 on page 19

GRAMIX® BRONZE BEARINGS AND IN NEW Sunbeam PRODUCTS

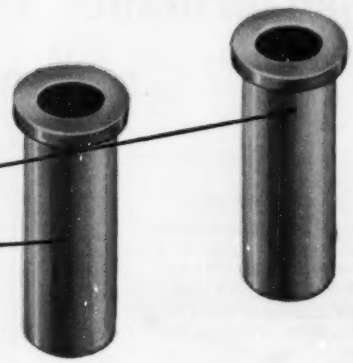
GRAMIX® ALLOYS

(PRODUCT OF POWDER METALLURGY)

The new Sunbeam Mixmaster Junior* does kitchen mixing chores quickly and efficiently and one of the important factors in its fine performance is the use of GRAMIX bearings on the beater spindle shafts. These sintered metal bearings, which are produced from GRAMIX Grade 81 alloy, are oil-impregnated for self-lubrication and are quiet running in operation. One of the outstanding features of these GRAMIX bearings is the fact that they are exceptionally long in relation to the comparatively small diameter. Yet there is no taper or "bell mouth" effect present and tolerances are held to .001 on both the ID and OD. The bearing offers maximum load-carrying surface throughout its length. In addition, Sunbeam engineers have found that GRAMIX gives them a controlled, consistent density in all sections of the bearing. This is another case where GRAMIX bearings have been specifically engineered and produced to fit the needs of the application. Can the same be done for your products?

**Made and guaranteed by the Sunbeam Corporation, Chicago, Illinois*

NEW SUNBEAM MIXER WITH GRAMIX SELF-LUBRICATING BRONZE SHAFT BEARING



117

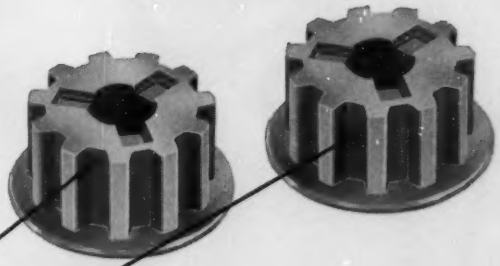
THE UNITED STATES

GRAPHITAR® CARBON-GRAPHITE • GRAMIX® SINTERED METAL PARTS • MEXICAN® GRAPHITE PRODUCTS • USG® BRUSHES

GRAMIX® IRON SPROCKETS

PROVE VERSATILITY OF

NEW SUNBEAM ELECTRIC LAWN MOWER WITH IRON GRAMIX DRIVE SPROCKET



In the new Sunbeam twin blade electric lawn mower, power is transmitted from the motor to the cutting blades via cog belt drives. Among the most important parts in this power transmission system are a pair of drive sprockets which must stand up under hours of rugged operation. For these critical parts, Sunbeam Corporation engineers have specified GRAMIX sintered metal sprockets produced to their exact specifications from GRAMIX iron alloy 78. This dual purpose part acts as both a bearing and a sprocket. The excellent bearing characteristics of this GRAMIX alloy eliminates need for special inserts etc., yet the sprocket itself withstands shock loading and maintains a constant coefficient of friction. The contour of the sprocket teeth is maintained under the most severe operating conditions. Additional benefits that Sunbeam engineers have found in GRAMIX include the compatibility of GRAMIX with the belt material and the fact that there is less operational noise. Again, this is a case where the GRAMIX process has produced a part specifically engineered to meet exact product requirements . . . why not investigate the advantages of GRAMIX parts for your designs?

WRITE FOR THIS BOOK

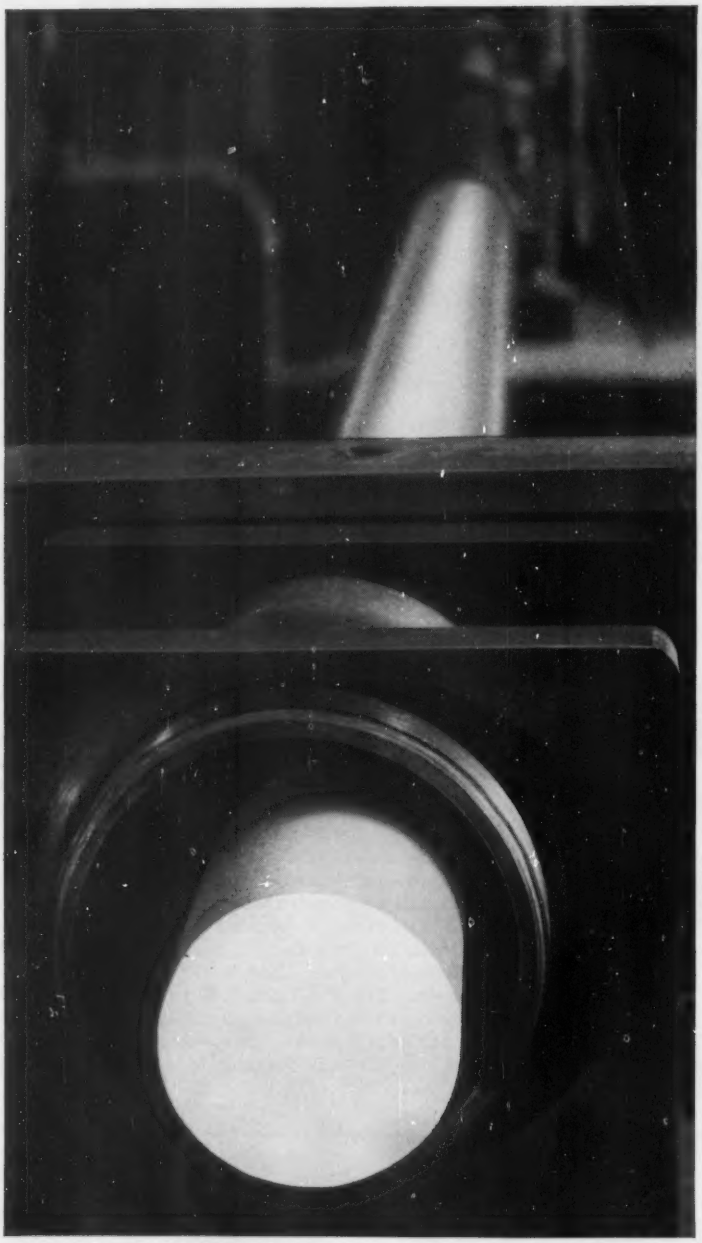
Because GRAMIX parts are die-pressed to shape, then sintered, they are usually much more economical than machined parts. Tolerances as close as .0005″ can be held, and the parts oil-impregnated for self-lubrication. Other facts of value to the manufacturer and the design engineer are contained in GRAMIX Engineering Bulletin No. 21. Write today to The United States Graphite Company, Saginaw, Mich.

GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION, SAGINAW 7, MICHIGAN

Circle 432 on page 19

THE NATIONAL SCENE

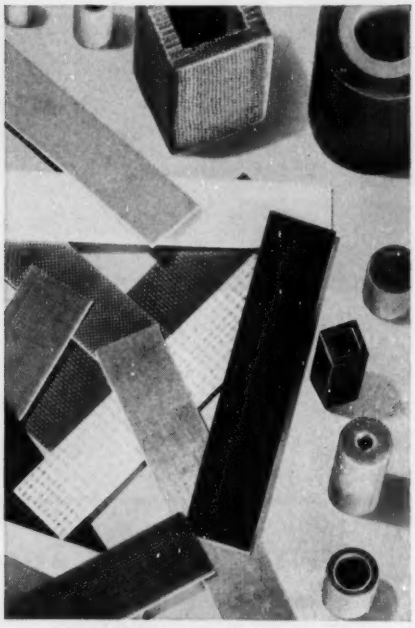


FAMOUS NYLON JOINS NATIONAL'S MATERIALS FAMILY. Proved in thousands of tough applications, versatile Nylon now becomes more useful to the designer than ever. National makes it so in extruded rods and 100% usable finished fabricated parts. Standard rod sizes range from ¼" through 2" in 3 and 6-foot lengths. Inquiries on other sizes and shapes are invited. National's expert engineering counsel assures the commercial soundness and economy of your product. And men, machines and capacity place National in a unique position to serve your immediate needs.

NATIONAL CAN HELP YOU reduce unit product cost or improve product performance at no added cost. Here's why: You can select the "one best material" from over 100 grades of PHENOLITE®, Vulcanized Fibre and NATIONAL Nylon—*without compromise in* properties or cost. You can simplify production and purchasing with the *timed delivery* of 100% usable parts—*from a single reliable source.* You gain competitively with National's new materials and grades *—the direct results of programmed materials-research.*

You benefit by calling National first. Check Sweet's PD File 2b/Na, the Telephone Directory Yellow Pages, or write Wilmington 99, Delaware, Dept. G.

MACHINING SKILL GIVES 100% USABLE PARTS as exemplified by this precision-turned 4-40 thread screw of Nylon. National has the skills and equipment to fabricate almost any part you design. Whether your order requires the simplest punching process or the most complex screw machine operation, you get the same result: *100% usable parts.*



INDUSTRY'S BROADEST LINE OF BASIC MATERIALS gives you greatest design freedom. With the addition of Nylon, the National line of materials—already industry's most extensive—grows to more than 100 grades and combinations. These include Vulcanized Fibre and PHENOLITE® Laminated Plastic. The result is greater selectivity for you—unbiased recommendations from National—and virtually any combination of properties you desire.

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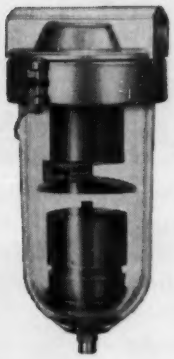
Circle 433 on page 19

Good News Norgren

for design engineers and PLANT ENGINEERS

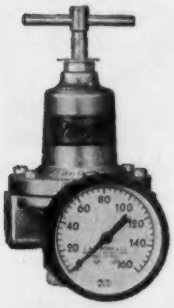
ANNOUNCES

Important New Developments in Compressed Air Filters and Pressure Regulators



NEW Norgren Air Line Filters

- **LESS PRESSURE DROP** — larger passages and larger filter element.
- **BETTER LIQUID REMOVAL** — Improved louver plate and baffle design. Removes more liquid from the compressed air line.
- **CHOICE OF FILTER ELEMENT**—interchangeable filter elements, 74, 64, or 25 micron.



NEW Norgren Pressure Regulators

- **GREATER ACCURACY OF REGULATED PRESSURE** — balanced valve and increased effective diaphragm area provide improved accuracy over a wide operating range.
- **RELIEVING OR NON-RELIEVING TYPE AVAILABLE**
- **IMPROVED RELIEVING CHARACTERISTICS** — automatic relief of excess pressure. Holds system pressure close to regulator setting.

For complete information...

call your nearby Norgren Representative listed in your telephone directory—or

WRITE THE FACTORY FOR NEW CATALOG.

C. A. NORGREN CO.

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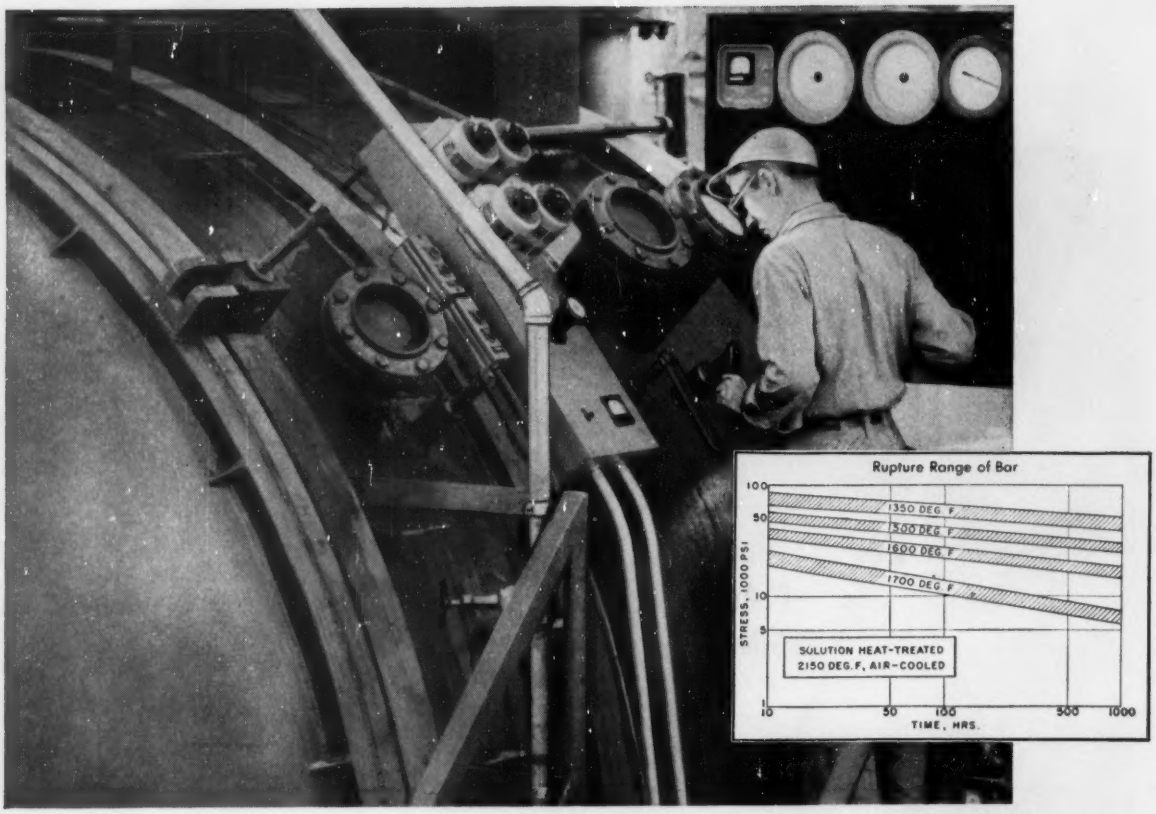

vacuum-melted HASTELLOY Alloy R-235

Trade-Mark

38,000 psi Stress-to-Rupture in 100 hrs. at 1500 deg. F

HASTELLOY alloy R-235 is a new precipitation-hardening, high-temperature alloy with outstanding properties through 1750 deg. F. In order to assure consistent high-temperature strength, it is melted and refined in special vacuum facilities at Haynes Stellite Company. The alloy has good oxidation resistance and a remarkable resistance to overaging in service. It is available in all standard wrought forms and can be forged, welded, and cold-worked. No lengthy or involved heat-treatments are necessary.

At room temperature, hot-rolled HASTELLOY alloy R-235 bar has an ultimate tensile strength of 167,000 psi, and a yield strength of the order of 100,000 psi. Strength and ductility remain relatively high from room temperature up to 1750 deg. F.

The strength of alloy R-235 under stress-rupture conditions is outstanding. Typical average stress-to-rupture in 100 hours at 1500 deg. F is 38,000 psi for bar stock, and about 37,000 psi for sheet. The alloy also has good impact strength.

If you would like information on the properties of HASTELLOY alloy R-235, get in touch with the nearest Haynes Stellite Company office. Ask for a copy of the new booklet, "HASTELLOY alloy R-235."

HAYNES TRADE-MARK ALLOYS

HAYNES STELLITE COMPANY

A Division of Union Carbide and Carbon Corporation

UCC

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Circle 435 on page 19

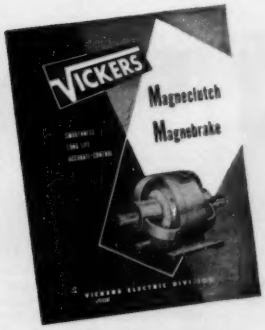
there's No Wear...

in the

VICKERS® MAGNECLUTCH

DRY MAGNETIC-PARTICLE CLUTCH

because there's no mechanical contact between torque transmitting surfaces



Vickers MAGNECLUTCH may also be used for braking and tension control. Get the complete facts. Write today for bulletin and application data forms.

There are no levers or linings—no spring, air or fluid pressures in the Vickers MAGNECLUTCH. Torque is transmitted by the linking action of magnetized finely divided ferromagnetic particles in the gap between driving and driven members. Torque is independent of speed, and is determined by the amount of energizing current. This torque transmission principle provides

CONTROLLED ACCELERATION*
SMOOTH OPERATION
NO GRAB OR CHATTER
LONGER LIFE

Vickers **MAGNECLUTCH** also Offers the Advantage of

TORQUE AT ZERO SLIP—
torque transmitted with 100% mechanical efficiency
TORQUE LIMITING—
torque easily adjustable from minimum to full rated torque
EXTREMELY FAST RESPONSE
SMALL CONTROL POWER
EASILY ADAPTED TO REMOTE CONTROL

*Equally close control of deceleration may be obtained with the Vickers MAGNEBRAKE.

VICKERS ELECTRIC DIVISION

VICKERS Inc. a unit of Sperry Rand Corporation

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Circle 436 on page 19

"I proved it to myself... and you can, too..

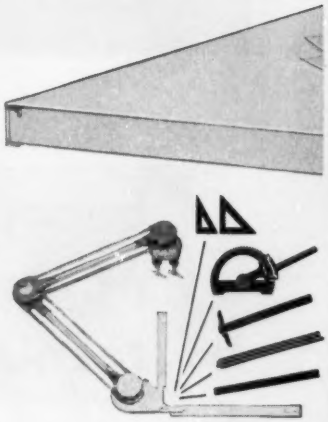
"BRUNING DRAFTERS DRAFTING JOBS BY 20

BRUNING DRAFTERS ADD MANPOWER TO THE DRAFTING ROOM — NOW WHEN YOU NEED IT MOST!

DRAFTSMEN! Prove it to yourself as have hundreds of skeptics who once frowned on using anything but conventional drafting tools like the T-square, triangle, and protractor. Bruning drafters actually speed drafting up to 40% on most jobs, up to 50% on some structural drawings . . . make your work far easier.

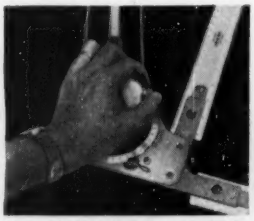
DEPARTMENT HEADS! The boom in production means pressure for more and more engineering drawings. With drafting space at a premium and experienced draftsmen hard to get, you couldn't find a faster or better way to add "manpower" than by boosting the output of your present draftsmen with modern, efficient Bruning drafters.

BRUNING DRAFTERS SPEED DRAFTING because they combine T-square, straightedge, triangle, protractor, and scales in *one* precision instrument. You eliminate the time and effort previously diverted to lifting, sliding, replacing, and reaching for these separate tools. Easily and quickly, you rotate, turn, and lift your Bruning drafter—all with the left hand. With fast fingertip control, you set and lock scales to any base line or angle. You accomplish everything that you can do with the conventional five basic instruments—only you do it much faster and much more accurately!

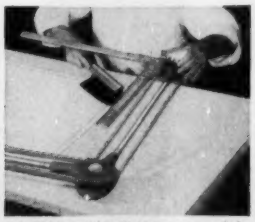


WHY BRUNING DRAFTERS ARE EASY TO OPERATE!

Bruning design permits complete 360 degree rotation about both the head and mast, making all parts of the board easily accessible—scales remain parallel to original angle setting. Patented Equipoise mechanism counteracts gravity on slopes up to 15°, literally "floats" your drafter into place without sag or "kickback." Exclusive Scalock device makes it easy to change scales, holds scales rigid while in use.



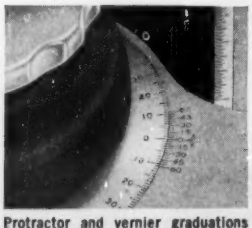
Automatic indexing stops at 15° intervals are engaged and released by just a press of the button on Bruning's unique Touch Control.



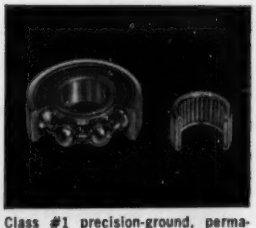
A ball-type joint between arms lets you lift your drafter over objects without unbalancing the machine or disturbing alignment of scales.

WHY BRUNING DRAFTERS ARE TOPS IN PRECISION AND DURABILITY!

Protractors have engine-divided graduations and double verniers reading to an accuracy of 5 minutes on most Standard models, to one minute on Civil Engineer models. A mathematically precise system of pulleys, machined to a tolerance of 0.0002", assures that drawing edges remain absolutely parallel to their original angle setting. Sturdy construction of the finest materials insures lasting accuracy and trouble-free operation.



Protractor and vernier graduations are set flush in the same plane to eliminate parallax error. Easy-to-read graduations are engine divided for accuracy.



Class #1 precision-ground, permanently lubricated ball bearings and frictionless needle bearings assure accuracy, effortless operation, and long life.

SPEED TO 40%!"

BRUNING

EQUIPOISE

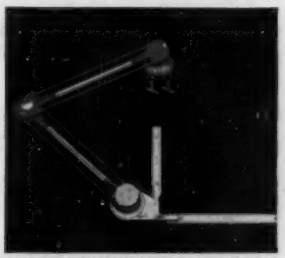
DRAFTING MACHINES

Exclusive Equipoise gravity compensator—finest on the market—permits use of drafter on inclined boards.

Standard protractor models—for mechanical, architectural, and structural draftsmen—are equipped with automatic indexing stops at 15° intervals. Civil Engineer protractor models—for civil, municipal, and utility engineers—have an azimuth scale, magnifier, and micrometer adjusting wheel. Arm lengths available to cover board areas from 36″x60″ to 48″x96″. Wide variety of scales. No extra charge for left handed models.

BRUNING TRACK DRAFTERS bring new space-saving efficiency and accuracy to firms that need extra-large drawings. Both single-arm and double-arm models offer automatic indexing, double verniers, and fast scale changes. Models are available to provide vertical coverage up to 84″, unlimited horizontal coverage.

BRUNING COUNTERBALANCED DRAFTERS provide unusual speed, and accuracy in vertical drafting. Available with Standard or Civil Engineer head and same arm lengths as Equipoise drafters.



BRUNING DETAIL DRAFTERS are a lighter, more compact, and less expensive variation of larger Bruning machines. Ideal for smaller drawings and use in shops, schools, and in the field.

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4700 Montrose Ave., Chicago 41, Illinois

Please send me the free, 20-page booklet on Bruning drafting machines.

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Company_____

Address_____

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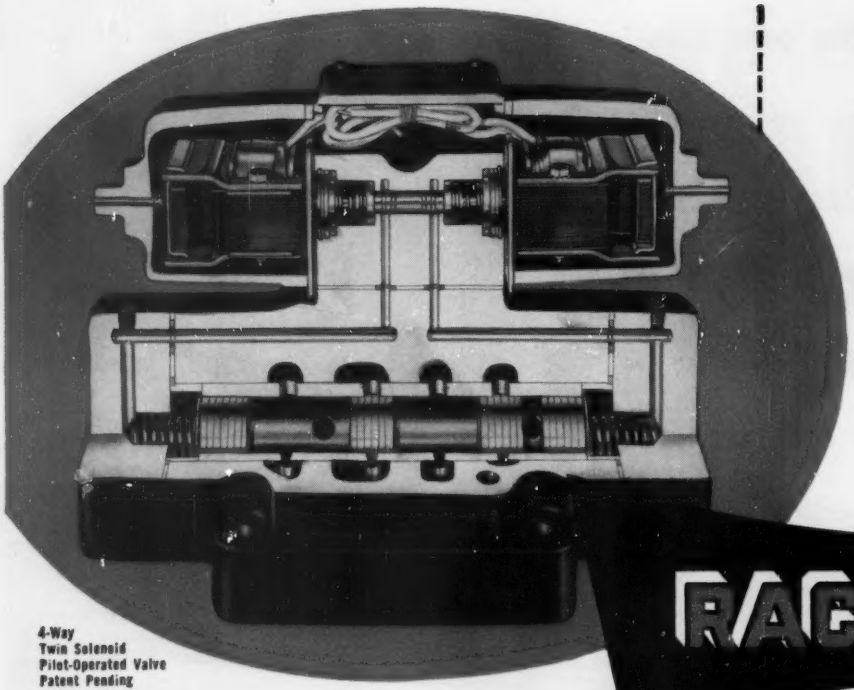


4-Way
Twin Solenoid
Pilot-Operated Valve
Patent Pending

RACINE®

SLEEVE TYPE VALVES GIVE BETTER CONTROL

Proper control of oil flow improves the operation of your machines.

RACINE Sleeve Type Valves are designed with round drilled parts that assure smooth, control of oil to cylinders and fluid motors.

These RACINE Valves are provided with dust-proof solenoid covers — a pending patent includes a RACINE feature that prevents solenoid operation and injury to operator when covers are removed or loose.

Built to J.I.C. specifications RACINE Valves are approved for use in all critical applications. They are precision-built, compact, and rugged in design. Operating pressures to 2000 psi with full back pressure on exhaust port.

Your machine will operate better, with less maintenance because of longer life of RACINE Sleeve construction. Write today for complete catalog showing why "Sleeve Type Valves give Better Control."

OTHER RACINE
HYDRAULIC PRODUCTS

MODEL Q
Variable Volume
Vane Type
Hydraulic Pump

PRESSURE BOOSTER
Up to 5000 psi
Up to 7:1 pressure ratio

FLUID MOTOR
Vane Type
50 to 3500 rpm
Pressures to 1500 psi

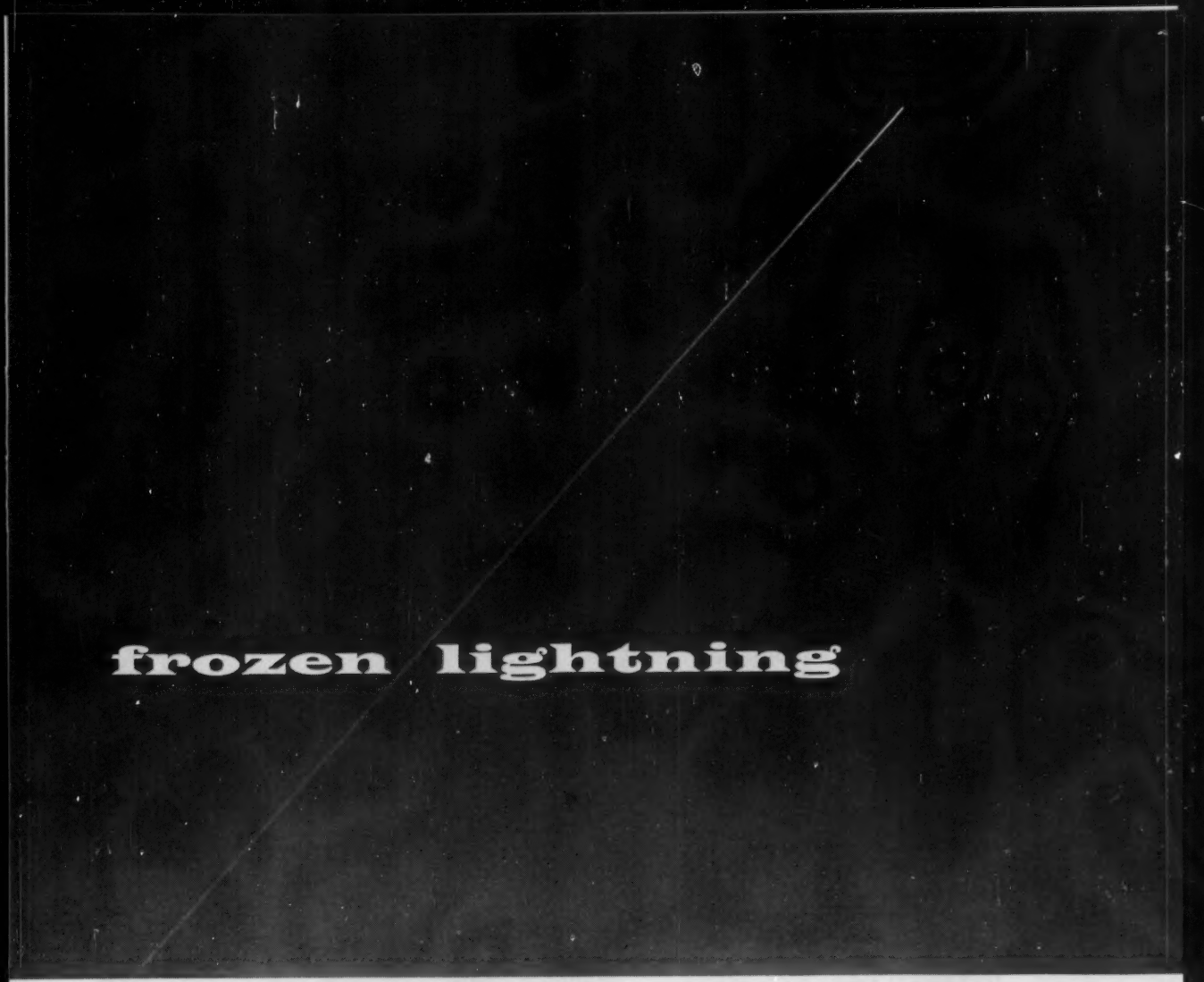
RESERVOIR
With Control Panel
Designed to your space
and circuit requirements

RACINE

NFPA NATIONAL FLUID POWER ASSOCIATION

RACINE HYDRAULICS & MACHINERY, INC.
2073 Albert Street
RACINE, WISCONSIN, U. S. A.

Circle 438 on page 19



The Germans called the upper-atmosphere trails of their V-2 rockets "frozen lightning". When the Mach 4-5 aircraft now under development fly at 80-90,000 feet and higher, we'll be seeing frozen lightning in our own skies.

Not freezing but heating will be the *real* problem at these ultra high speeds. At 3000 mph, the skin and many structural components will be heated to over 1000°F, temperatures too high for alloys now used. Needed: materials strong up to 1200-1300°F for structural forgings and other stressed parts.

Engine builders, fastener manufacturers and forge shops are handling similar requirements right now, with Carpenter alloys. These alloys have gained an enviable reputation for uniform high quality, ability to meet tough specifications consistently, improved forgeability and exceptional cleanness. Forging tolerances can be tighter. Finishes are better. Rejects are far fewer.

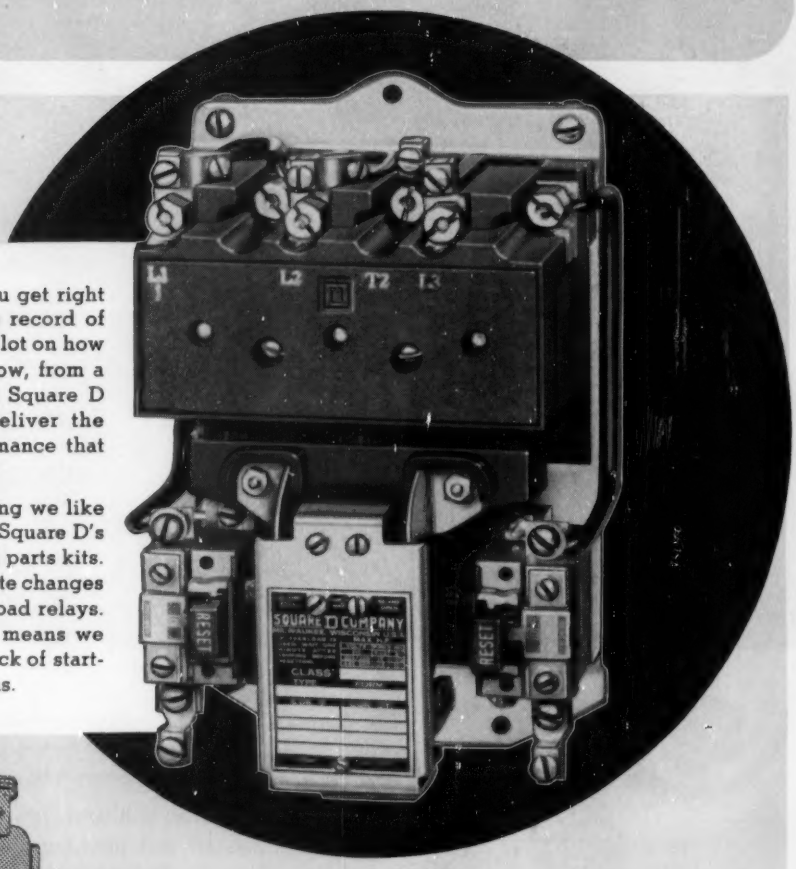
Design properties and fabrication instructions for these alloys are summarized in our new booklet, "Carpenter Alloys for Elevated Temperature Service". For your copy drop us a line on your Company letterhead. The Carpenter Steel Company, 120 W. Bern Street, Reading, Pa.

Carpenter STEEL

Improved alloys for elevated temperature service

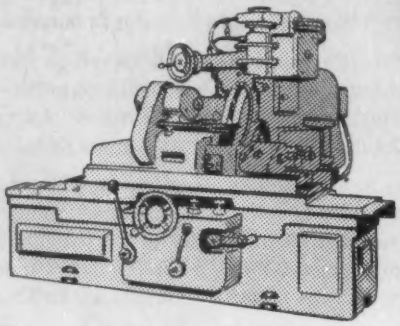
Circle 439 on page 19

Here's Why We Use SQUARE D Starters on the Machines We BUILD



PERFORMANCE When you get right down to it, the performance record of any machine tool depends a lot on how the control behaves. We know, from a lot of past experience, that Square D starters are designed to deliver the kind of trouble-free performance that keeps our customers happy.

FLEXIBILITY Another thing we like is the flexibility we get with Square D's starter design with packaged parts kits. It's a cinch to make last-minute changes in interlocks, coils and overload relays. That's important because it means we don't have to keep a big stock of starters with a lot of modifications.



FIELD ENGINEERING SERVICE

When we're designing machines that call for more complicated electrical control, it's mighty nice to have a Square D Field Engineer handy to work with us. As a matter of fact, he'll carry the ball just as far as we say—even to developing the control circuit for a multi-station machine.

NOW...EC&M PRODUCTS ARE A PART OF THE SQUARE D LINE!

SQUARE D COMPANY

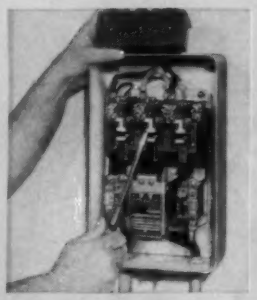
Here's Why We Specify
SQUARE D Starters
on the Machinery We BUY

PERFORMANCE, EASY INSPECTION AND MAINTENANCE

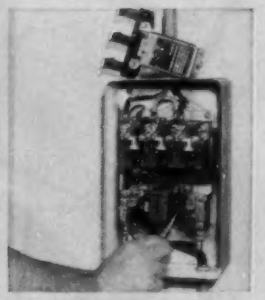
Sure, we like Square D performance because it keeps our "down time" at a minimum. BUT—everybody knows that even the best starter needs periodic inspection and preventive maintenance. We like the way Square D makes it easy to handle those routine jobs.

OFF-THE-SHELF PARTS KITS

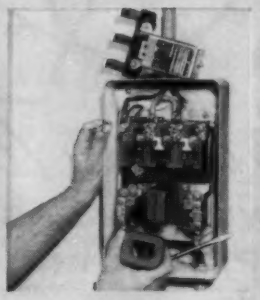
They make normal maintenance and modifications easier than ever. Packaged parts include interlocks, contacts, coils, overload relays, pushbuttons and selector switches. They're easy to buy, easy to identify, and faster to install.



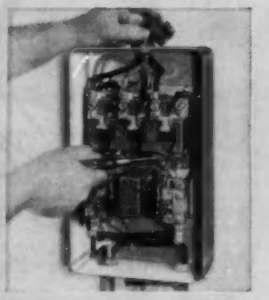
1 Loosen two screws and the arc chamber cover comes off. Every contact surface can be inspected at a glance.



2 Remove four screws and entire movable assembly can be lifted off. Disconnect two wires and slip off magnet coil.

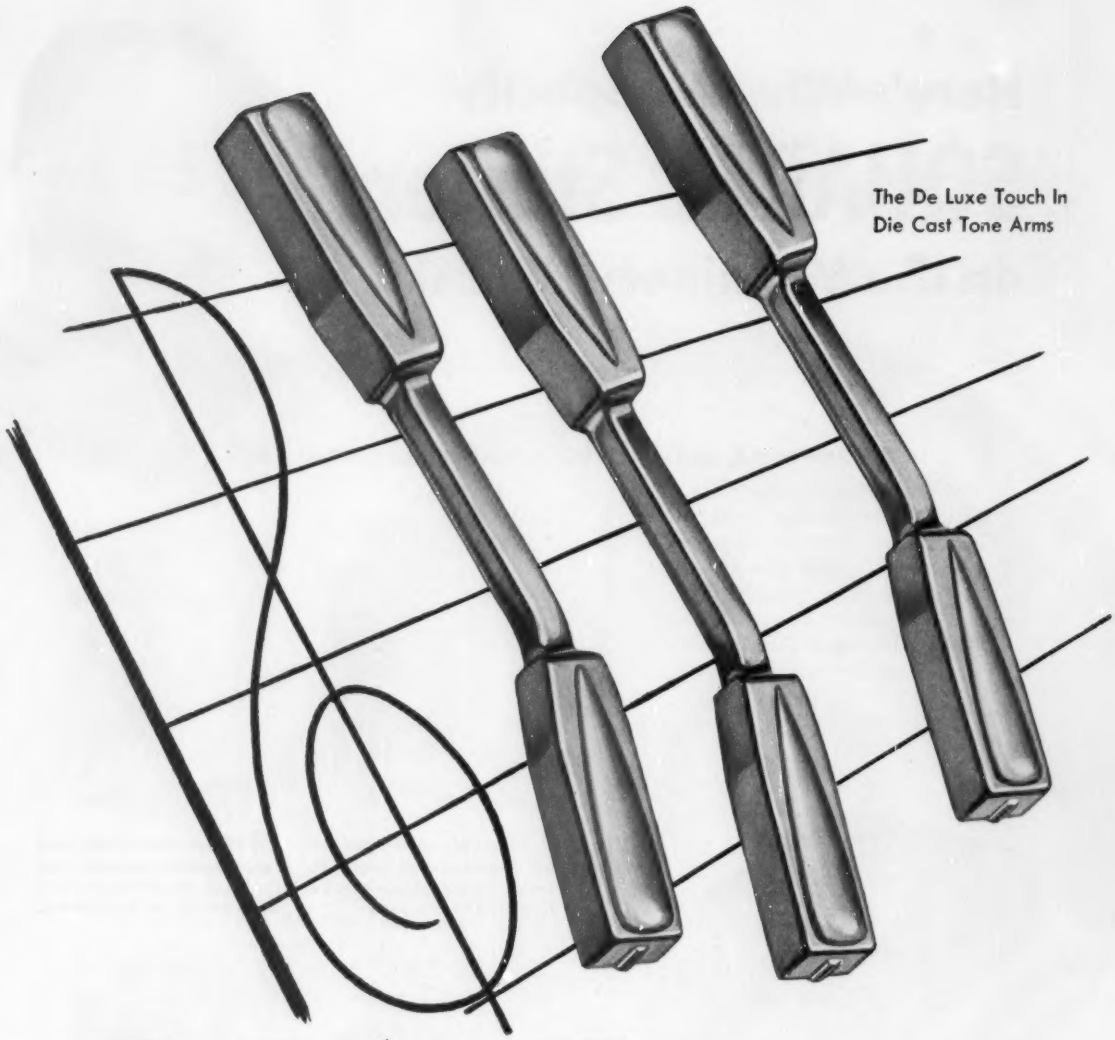


3 Contacts are attached with separate screws—they can be removed and replaced without disturbing any wiring. A screwdriver is the only tool needed.



4 Sizes 0 through 4 starters have these separate mounting electrical interlocks for easier installation. Contact block is attached from front of panel with two screws.

Everybody's Ahead with Square D!



The De Luxe Touch In
Die Cast Tone Arms

The De Luxe Touch—

TEMPERED BY A LOW COST PROCESS WITH MADISON-KIPP ZINC AND ALUMINUM DIE CASTINGS

The designer of quality products must watch his costs vigilantly to avoid drastically reducing his market potential pricewise.

Fortunately, the "DeLuxe Touch" is available without cost penalty and usually at a big saving by utilizing the die casting process.

Full process utilization, however, is the telling factor. It is available at Madison-Kipp where the rare mechanical skills required, are predominant and seasoned.

Please clip this ad as a reminder to contact us when you have die casting requirements.

kipp

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210 WAUBESA STREET • MADISON 10, WIS., U.S.A.

Skilled in Die Casting Mechanics • Experienced in Lubrication Engineering • Originators of Really High Speed Air Tools

Circle 441 on page 19

Circle 442 on page 19→

Imagine a mile-wide ball with surface finish accurate to within 1/16"

If Hoover could make this giant bearing ball—one mile in diameter—and maintain Hoover quality of precision manufacture, the immense sphere would be so smooth that surface finish would be accurate to within 1/16 inch!

In actual terms, the surface smoothness of a Hoover Ball is measured on a micro-inch basis. Roundness and diameter are held within 25 millionths of an inch. Microscopic precision, both in smoothness and spherical accuracy, means quality in Hoover *Micro-Velvet* Lapped Balls.

Equipment which will measure surface quality to a fraction of one millionth of an inch is used to check and re-check Hoover Balls. A perfectly matched set of *Micro-Velvet* Balls goes in each bearing.

These precision-made balls team up with the ultra-smoothness and minutely exact curvature perfection of famous *Hoover Honed* Raceways.

The result . . . equalized load, high capacity, and quiet operation, assuring superior operating performance and long life.

Investigate Hoover's complete line of balls, made in many metals, as well as light, medium and heavy series ball bearings. Engineering assistance is readily available to manufacturers. Write for information.

hoover

BALL AND BEARING COMPANY, ANN ARBOR, MICHIGAN

Hoover Honed and *Micro-Velvet* are Hoover Trademarks.

HOOVER HINTS:

Factors Involved In Bearing Selection

Application is the key to bearing selection. The importance of a bearing's characteristics is relative to the job it must do. Usually one of the most important factors is the capacity or load-carrying ability. Also important in many applications is the type of loading—thrust, radial or combined . . . the amount of friction involved . . . the ease of assembling a bearing into a unit . . . the danger of misalignment . . . the limiting maximum speed.

All types of anti-friction bearings are concisely compared and analyzed from an engineer's standpoint in "Engineer's Handi-Book of Anti-Friction Bearings." Send for yours now.

Hoover Ball and Bearing Company,
Ann Arbor, Michigan.

Mail my copy of "Engineer's Handi-Book of Anti-Friction Bearings."

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9

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ELECTRICAL ENGINEERS

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Salary will depend on experience; progress for the right man can be rapid. Headquarters are in Cleveland with opportunities for travel to attend engineering meetings and expositions.

If you are interested, send full details of your engineering background to the Editor, MACHINE DESIGN, Penton Building, Cleveland 13, Ohio.

Circle 443 on page 19

WHEN FLUID POWER ENTERS YOUR PROJECT

call the man from Webster

. . . one of a staff of engineers, specially trained in hydraulic applications.

He is ready to come to your plant, work with your people, explore new ideas, application or system problems. His knowledge of the unique, flexible design advantages of Webster pumps and valves enables him to adapt standard components to solve most special problems . . . with resultant cost savings.

Write or call the man from Webster — a good man to have on your design team.

OIL HYDRAULICS DIVISION

WEBSTER ELECTRIC

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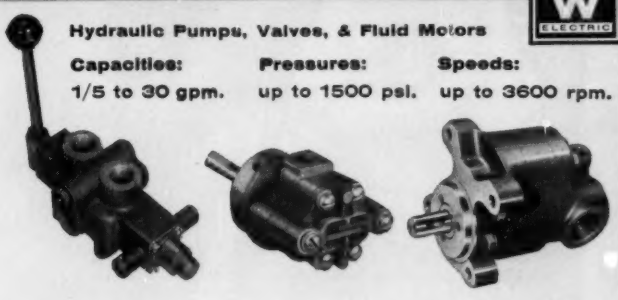
Hydraulic Pumps, Valves, & Fluid Motors

Capacities:	Pressures:	Speeds:
1/5 to 30 gpm.	up to 1500 psi.	up to 3600 rpm.



☐ *Have THE MAN FROM WEBSTER contact us—*

- Please send the following -

☐ *Complete catalog of pumps and valves*

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Company _____

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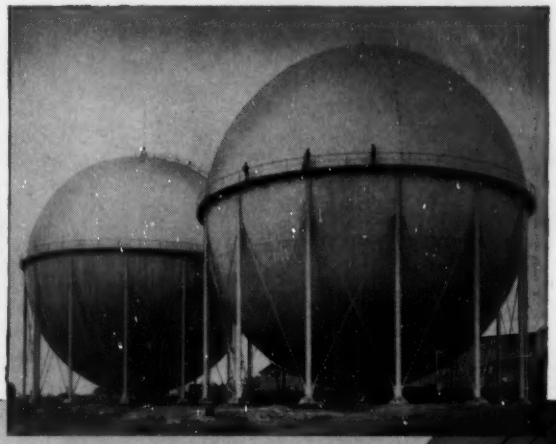
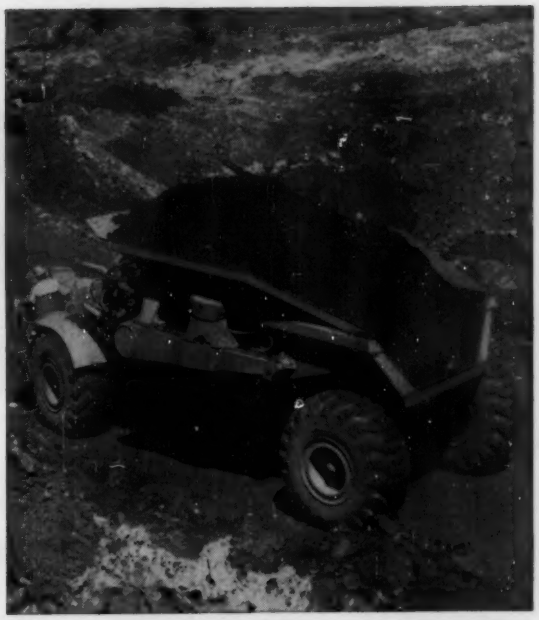
franklin adv. H100

HOW USS "T-1" STEEL IMPROVES



They Couldn't Be Built Without "T-1"... Only the unique combination of properties found in USS "T-1" Steel—very high yield strength, toughness, and excellent weldability—could make these two huge pressure vessels possible. In carbon steel, the shell walls cannot be over 1¼" thick—the maximum permissible without stress relieving after welding. The diameter would therefore be restricted to 79.17 feet. As a result, 6 vessels, weighing 2½ times as much, would have been required to provide the same capacity as just these *two* USS "T-1" Steel vessels. These vessels—each 110½ feet in diameter, with a net capacity of 707,000 cu. ft. and shell walls only 0.73" thick—were erected in Japan for Tokyo Gas Works, Ltd. They were designed and fabricated in the United States by Chicago Bridge & Iron Company.

THESE PRODUCTS:



75-Mile Trip Eliminated—Now made of USS "T-1" Steel, the forks on this lift truck no longer need to be sent 75 miles for heat treatment. In addition, the high strength of the new steel reduced the width and thickness of the forks. This lift truck is the largest standard-line lift truck on pneumatic tires in the world. Manufactured by Gerlinger Carrier Company, Dallas, Oregon, it is shown here in use at Baltimore Concrete Plant Corporation.

More Ore, More Often—The great strength of USS "T-1" Steel helps boost the volumetric capacity, reduce the weight, and speed operation of this new rear-dump trailer that is used to haul high-volume, lightweight materials. Drawbar and draft frame structure, as well as all load-containing body plates, were fabricated from USS "T-1" Steel. This permitted working stresses above those permissible with commonly used steels and resulted in a weight saving of 3½ tons. Trailer was designed and built by Athey Products Corporation, Chicago, Illinois.

YOU GOOD AT GUESSING WEIGHT?

You can win a prize at the Design Engineering Show in May by just guessing the combined weight of the flame-cut steel "T" and "1." Stop at the United States Steel exhibit to see this steel trademark, make your calculations and enter your guess. You could easily be one of the winners of the useful prizes which will be awarded.

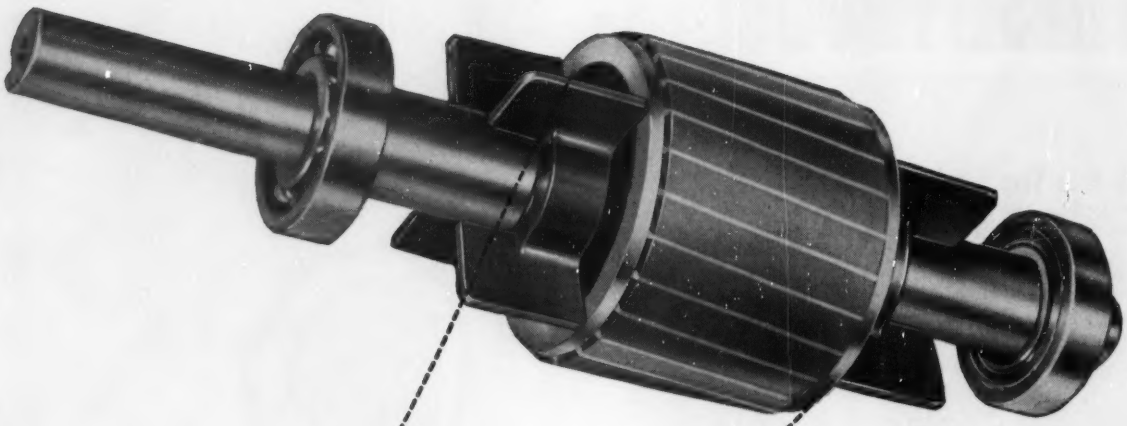
Meanwhile, though, send for your copy of the new and revised booklet about USS "T-1" Steel. It contains up-to-date information on properties, applications and fabrication of this remarkably versatile constructional alloy steel. Write to United States Steel, Room 5572, 525 William Penn Place, Pittsburgh 30, Pa.

UNITED STATES STEEL CORPORATION, PITTSBURGH • COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA. • UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS "T-1" CONSTRUCTIONAL ALLOY STEEL

USS

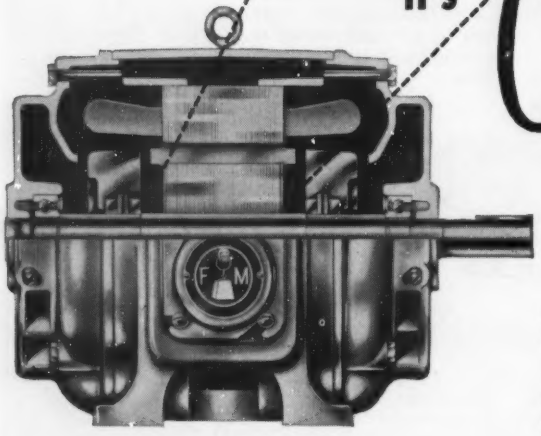
UNITED STATES STEEL



When you want motor performance

You want this Rotor design...

it's Copperspun



Long life, stamina and high efficiency—made possible by the Copperspun rotor found only in Fairbanks-Morse polyphase squirrel-cage induction motors.

Before specifying motors for sustained, heavy-duty drives, compare designs of the all-important rotor.

Fairbanks-Morse Copperspun rotors have the mechanical strength and the superior electrical and thermal characteristics of copper. Compare these advantages against aluminum or white metal alloys. Exclusive F-M method of centrifugal casting produces a truly one-piece rotor that is homogeneous, free from flaws and gas inclusions—virtually indestructible. It is accurately machined and dynamically balanced for longest trouble-free service on the toughest application.

The Copperspun rotor and the Fairbanks-Morse standard of quality manufacture make it more than worth your while to get in touch with the motor specialist from Fairbanks, Morse & Co., Dept. MD-2, Chicago 5, Ill.

FAIRBANKS-MORSE

a name worth remembering when you want the BEST

ELECTRIC MOTORS AND GENERATORS • DIESEL LOCOMOTIVES AND ENGINES • PUMPS • SCALES • RAIL CARS • HOME WATER SERVICE EQUIPMENT • MOWERS • MAGNETOS

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Never before on a Power Plane... a motor that spins at 25,000 RPM!

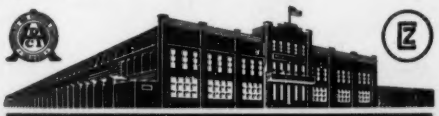
CASE HISTORIES FROM MT. VERNON FILES

No power plane before this Porta-Plane* has ever used such a high speed motor. And when any manufacturer is out to break all precedents, and still sell his product at a low price, he needs every bit of designing and production skill he can find—anywhere.

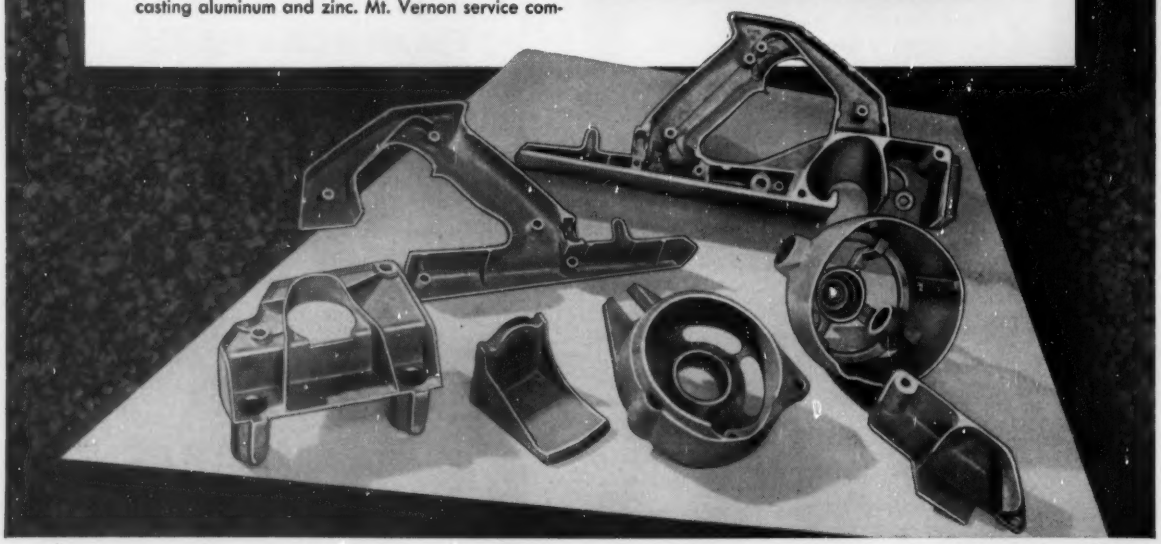
This manufacturer found these in generous abundance at Mt. Vernon. The 8 principal parts of the frame of the Porta-Plane were designed to obtain the special advantages of die casting: thin wall sections of great strength and rigidity, negligible machining, smooth finish, high speed production, low cost.

This important advantage—low cost—stems directly from the way we are organized here at Mt. Vernon. From die cast to finished casting, Mt. Vernon has both the complete die casting service and the facilities it takes to produce parts like these at minimum cost in any quantity. We have 162,000 square feet of the most modern equipment for making dies and for die casting aluminum and zinc. Mt. Vernon service comprises completely coordinated designing, die-making, casting, and machining, all under one roof.

It will pay you to bring your production specifications to us. We may show you, as we did Porter-Cable, the way to important cost reductions and improved products.



MT. VERNON
DIE CASTING CORP.
STAMFORD, CONNECTICUT



high scorer

. . . and in high speed steels, it's always REX

Crucible's REX® high speed steel always scores highest on performance—as it has for more than a half century. That's because it is consistently sound and uniform in structure . . . with dependable response to heat treatment.

But don't take our word for it. Check REX for yourself—by any test you choose. You'll discover that recent improvements in manufacturing techniques have made it better than ever—why REX is today, as it's always been, *the standard by which all other high speed steels are compared!*

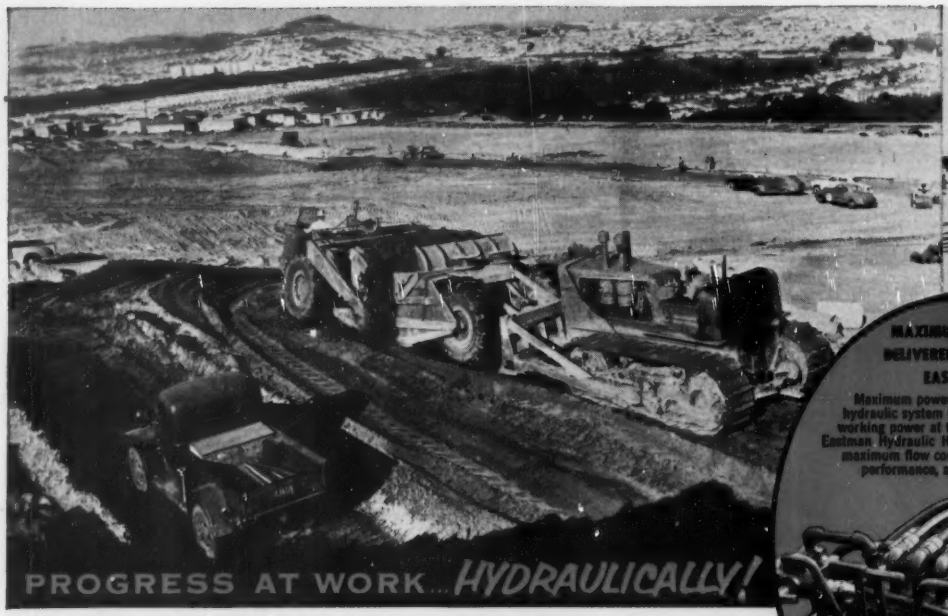
REX is immediately available at all Crucible warehouses, or on prompt mill delivery. For a list of helpful data on REX and other *special steels*, write for a free copy of the "Crucible Publication Catalog." *Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.*

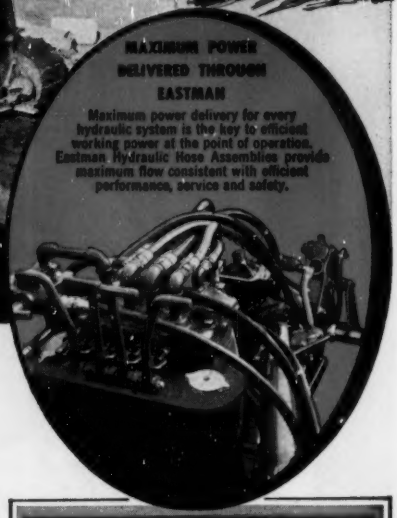
CRUCIBLE first name in special purpose steels

Crucible Steel Company of America

Canadian Distributor—Railway & Power Engineering Corp., Ltd.

Circle 449 on page 19




MAXIMUM POWER
DELIVERED THROUGH
EASTMAN
Maximum power delivery for every hydraulic system is the key to efficient working power at the point of operation. Eastman Hydraulic Hose Assemblies provide maximum flow consistent with efficient performance, service and safety.

SMOOTHER AND SAFER ROADS ARE BEING BUILT FASTER... THROUGHOUT AMERICA *with*

HYDRAULIC POWER delivered thru

EASTMAN HYDRAULIC HOSE ASSEMBLIES

Modern Hydraulics will put millions of horsepower to work building America's roads . . . maneuvering mighty earth-moving machines with finger-tip ease. Grading, loading, leveling and finishing will be easier, more economical—saving time, money and manpower.

Many Pioneer Manufacturers of modern road building equipment have, from the beginning of hydraulics—equipped their machines with Hydraulic Hose Assemblies made by the very first pioneer manufacturer in this field—EASTMAN of Manitowoc, Wisconsin.

Eastman's Continued Leadership has been maintained through advanced engineering and design—plus materials and workmanship which are so high that they are accepted by many Original Equipment Manufacturers as the *standard for the industry!*

Eastman Is Geared to supply the critical demand for performance-tested Hydraulic Hose Assemblies which will more than meet the roughest road building construction hazards. Many 'round the clock operations will now run into year-'round schedules, and Eastman's new production facilities stand ready to provide *dependable shipments, service and satisfaction.*

FOR INCREASED EFFICIENCY
IN HYDRAULIC POWER
Specify **EASTMAN**
HYDRAULIC HOSE ASSEMBLIES

EASTMAN'S NEW "HI-FLO" COUPLING DELIVERS A MAXIMUM OF POWER

EXCLUSIVE GRIP ADVANTAGES WITH INTER-LOCK ® CLAMP COUPLING

CUT COSTLY "DOWN-TIME" WITH EASTMAN RE-USABLE COUPLINGS

ADAPTERS AND ADAPTER UNIONS, STRAIGHT, ANGLED, TEES FOR HOSE ASSEMBLIES AND RE-USABLE COUPLINGS

BULKHEAD "O" RING ADAPTERS, HYDRAULIC TUBE FITTTINGS, UNIONS, ELBOWS, "O" RING ADAPTERS AND LOCKNUTS FOR ALL HOSE ASSEMBLIES, RE-USABLE COUPLINGS

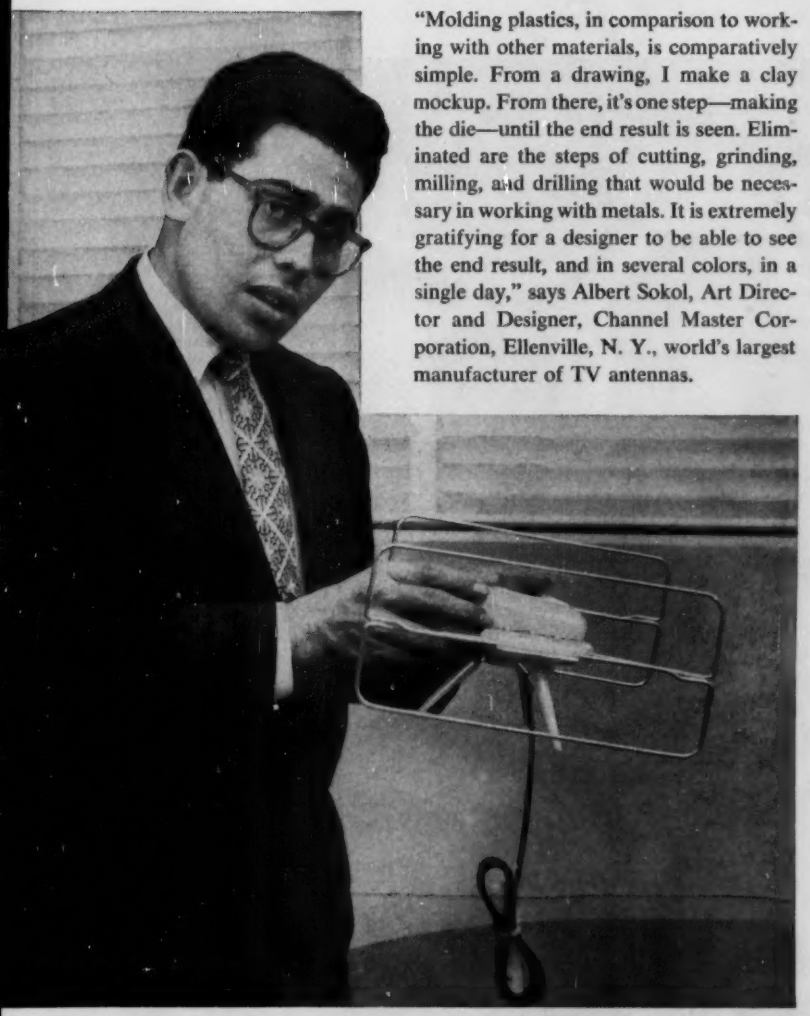
Eastman
first in the field

MANUFACTURING COMPANY
Dept. MD-2, Manitowoc, Wis.

WRITE **for bulletin to suit your needs or send specifications**

Circle 450 on page 19

Designer Albert Sokol talks plastics:



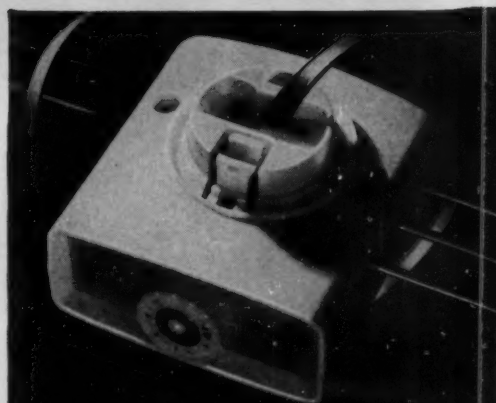
"Molding plastics, in comparison to working with other materials, is comparatively simple. From a drawing, I make a clay mockup. From there, it's one step—making the die—until the end result is seen. Eliminated are the steps of cutting, grinding, milling, and drilling that would be necessary in working with metals. It is extremely gratifying for a designer to be able to see the end result, and in several colors, in a single day," says Albert Sokol, Art Director and Designer, Channel Master Corporation, Ellenville, N. Y., world's largest manufacturer of TV antennas.

"A designer's responsibility is to create articles that are functional, have suitable strength and still please the eye. By using plastics, it is much easier for a designer to fulfill this function. The day of using plastics primarily as an economical agent is passing. Today, manufacturers are taking advantage of its aesthetic qualities.

"Developing our new Channel Master 'Showman' indoor TV antenna was a problem of electricity and aesthetics. Our research engineers did their job by compressing the shape into a unit that had greater efficiency. Then, designers utilized the shape, color and finish offered by plastics. *Vogue* magazine said that our 'Showman' antenna was 'the most eye-appealing indoor TV antenna ever designed.' I feel the endless possibilities of plastics allow designers in all fields to run the gamut of imagination."

Have you turned *your* imagination loose on the possibilities of plastics in connection with your products? Koppers plastics are doing outstanding jobs for manufacturers all over the country . . . they can do the same for you. Koppers manufactures DYLAN® polyethylene, SUPER DYLAN* polyethylene, DYLENE® polystyrene and DYLITE® expandable polystyrene. For more information on any of these fine plastics, write to Koppers Company, Inc., Chemical Division, Dept. MD-27, Pittsburgh 19, Pennsylvania.

**Koppers Trademark*



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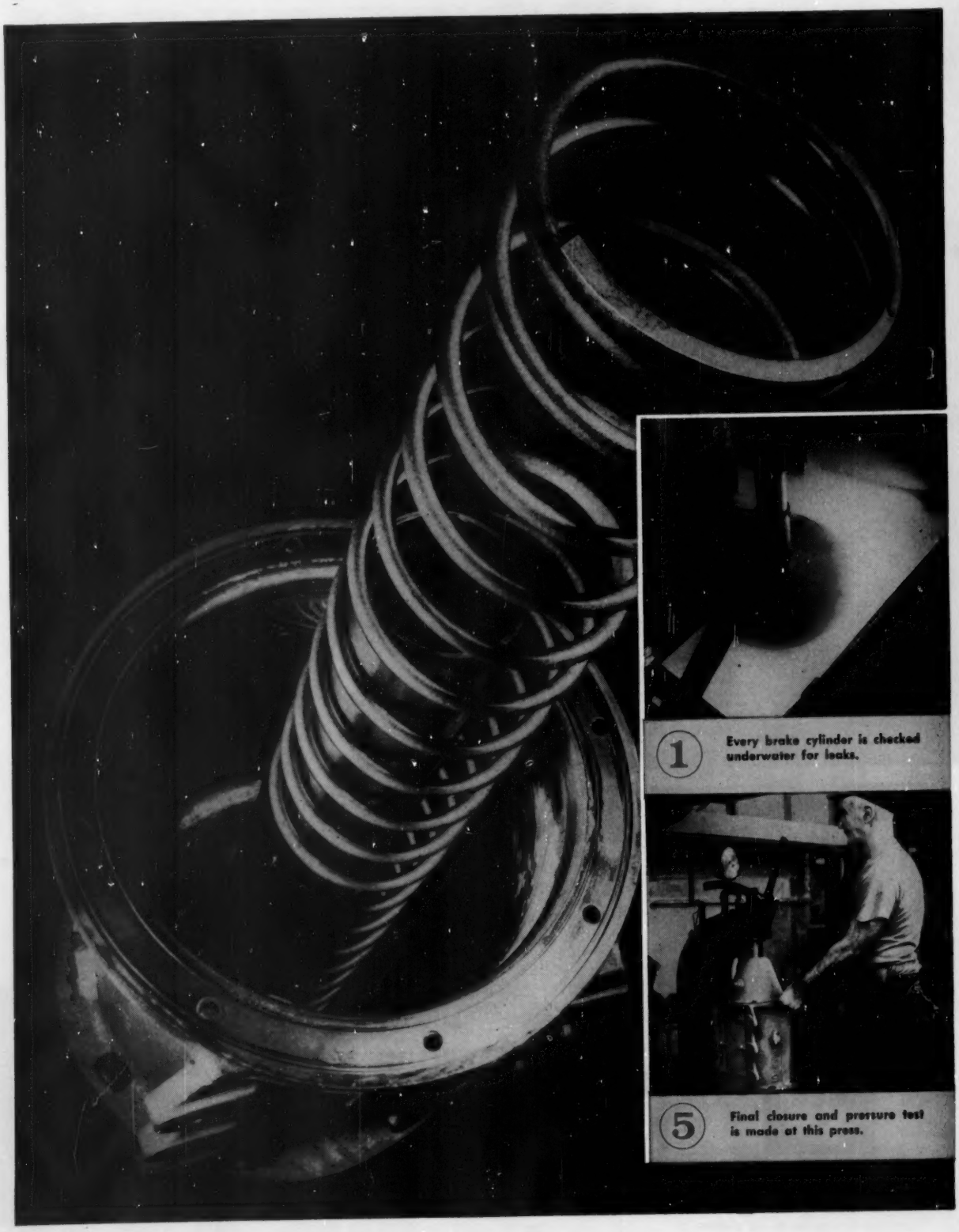
Circle 451 on page 19

Inside story of the most



1 Every brake cylinder is checked underwater for leaks.

5 Final closure and pressure test is made at this press.

famous brake in the world

Even schoolboys know the fabulous story of George Westinghouse, and how he accelerated developments of railroad transportation with his Westinghouse Automatic Air Brake. Even if a train breaks in two, brakes are applied to *each* section to stop it.

Although Westinghouse Air Brake Company has made countless improvements in braking devices, the basic operating principles have prevailed since 1872. Original design of some parts is still followed today, that's how well they were designed in the first place.

A good example is the release spring, which retracts the brake cylinder piston when the brakes are released. American Steel & Wire has been supplying this spring for about 75 years. And although better steels and heat treatment are always being used, this original spring design has been operating over a 160° F. temperature range, stressed hundreds of times monthly, and is currently in service on over 2 *million* freight cars all over the world.

We are proud of our long association with Westinghouse Air Brake Company, maker of the most famous brake in the world, considered by many people to be one of the great inventions of our time.

AMERICAN STEEL & WIRE DIVISION, UNITED STATES STEEL, GENERAL OFFICES: CLEVELAND, OHIO
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO, PACIFIC COAST DISTRIBUTORS
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA., SOUTHERN DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS AMERICAN QUALITY SPRINGS

2 Piston assembly. Westinghouse Air Brake Company makes its own rubber parts.

3 After piston is inserted, workman lubricates the cylinder.

4 Spring inserting. The housing is machined high-density cast iron.

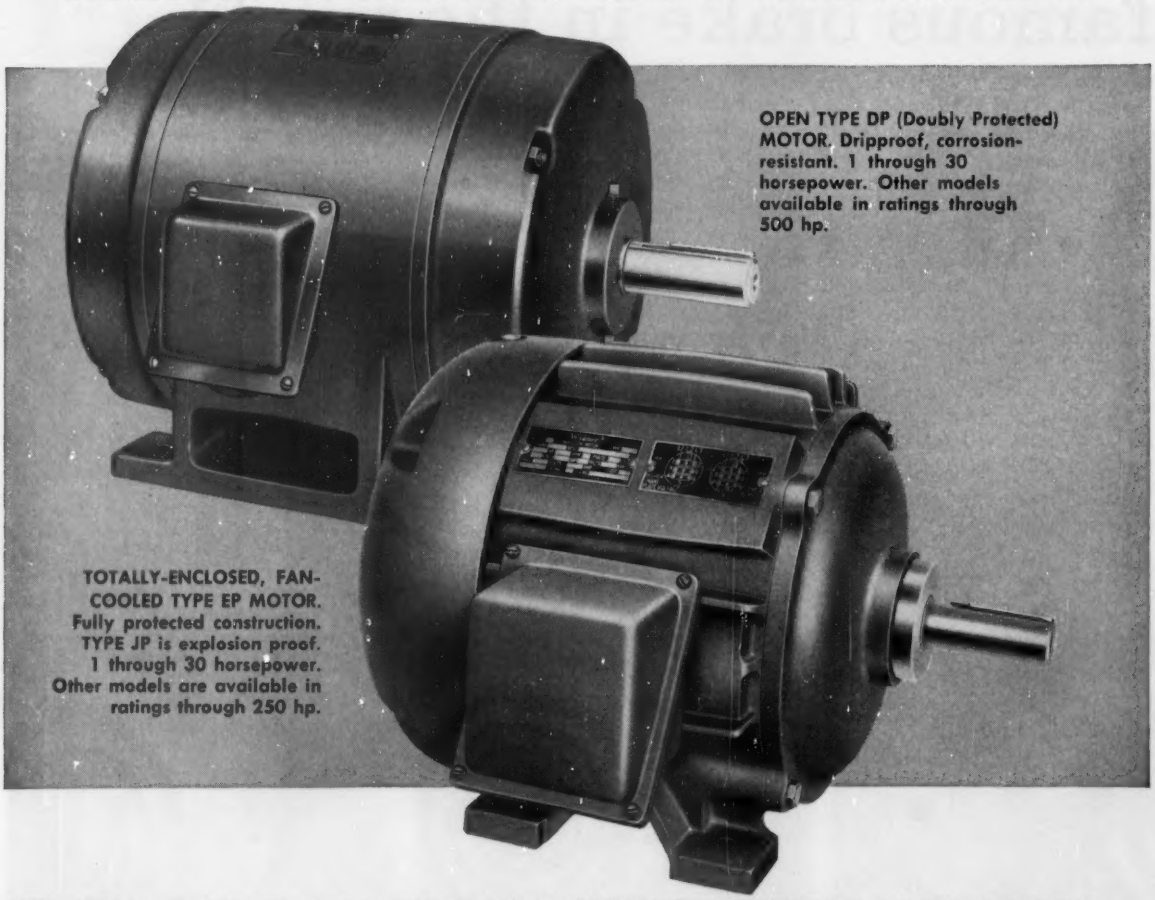
6 Cylinder at left is for freight cars, other is one of several used on a locomotive.

7 In position. Cylinders go three years between cleanings.

USS

UNITED STATES STEEL

WAGNER ELECTRIC MOTORS...THE CHOICE OF LEADERS IN INDUSTRY



OPEN TYPE DP (Doubly Protected) MOTOR. Dripproof, corrosion-resistant. 1 through 30 horsepower. Other models available in ratings through 500 hp.

TOTALLY-ENCLOSED, FAN-COOLED TYPE EP MOTOR. Fully protected construction. TYPE JP is explosion proof. 1 through 30 horsepower. Other models are available in ratings through 250 hp.

OPEN TYPE OR TOTALLY ENCLOSED MOTORS...

Wagner offers MORE for your motor dollar!

- **MORE POWER IN LESS SPACE**... These motors are built in NEMA frame sizes 182 through 326 U. They pack more power into less space for easier handling and stocking—require less space for installations.
- **CORROSION-RESISTANT FRAMES** ... Both types are built with rugged, corrosion-resistant cast iron frames. Motor feet are cast as an integral part of the frame for maximum strength and rigidity.
- **THE TYPE OF PROTECTION YOU NEED** ... Type DP motors have completely dripproof—virtually splash-proof enclosures; while type EP is totally enclosed, fan-cooled for complete protection; and type JP adds explosion proof features.
- **COOLER OPERATION**... Special baffles direct a cooling flow of air through the DP motor. Types EP and JP are fan-cooled and have ribbed frames to increase the surface area for more efficient cooling.
- **LONGER BEARING LIFE**... These motors can be re-greased when desired to prolong bearing life. Fresh grease can be added—old grease removed through openings provided in the bearing housing.
- **WAGNER DEPENDABILITY**... These two motors have the same high Wagner quality, will give the same long life performance, that have made Wagner Motors a *known* value for sixty-five years.
- Let a Wagner field engineer, expert on motor applications, show you how these motors can be applied to your needs. Call the nearest of our 32 branch offices, or write us. Bulletins MU-202 and MU-203 give complete information on these Wagner Motors. Write for your file copies today.

M57-4

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A copy for every designer

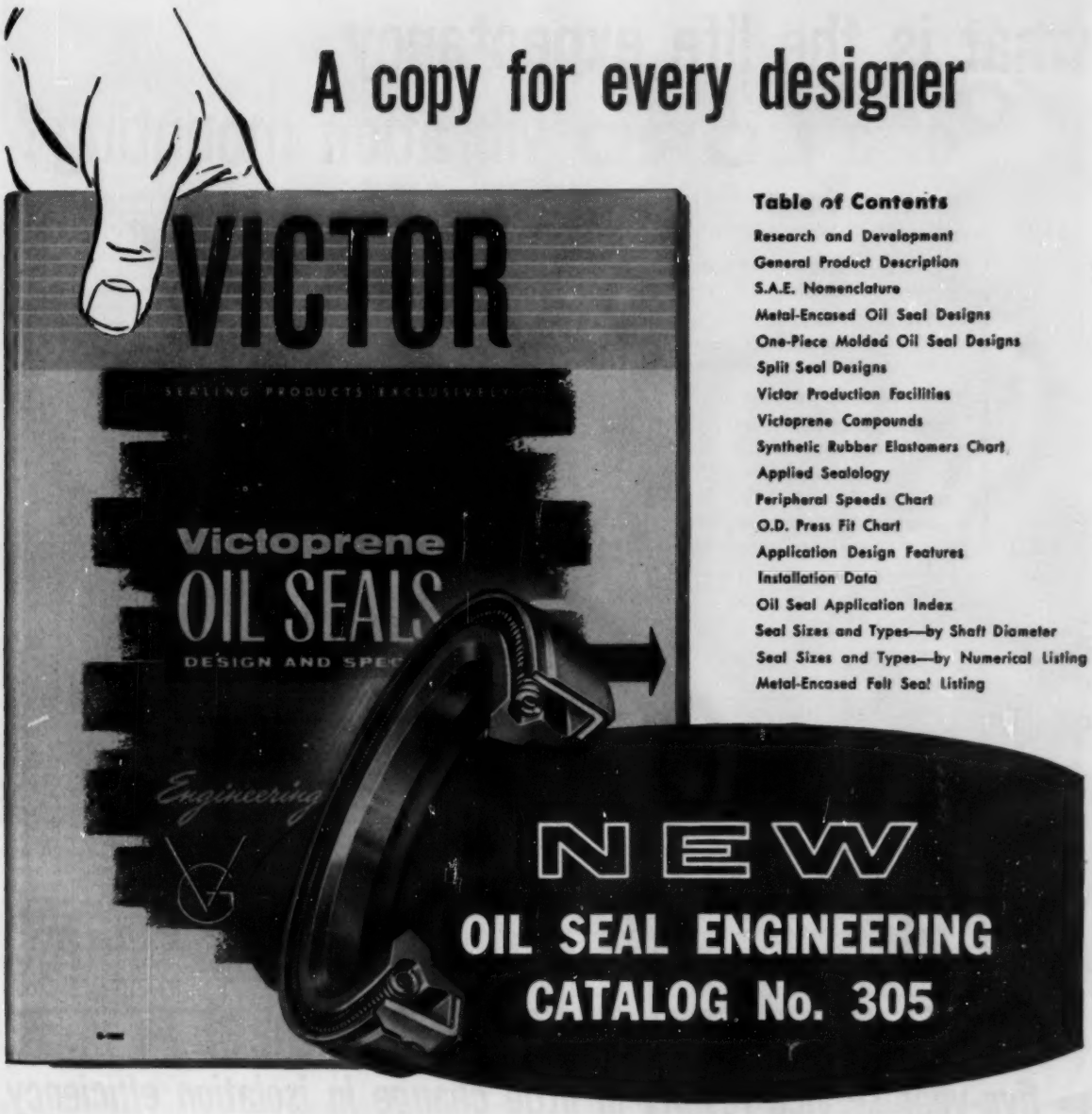

Table of Contents

Research and Development
General Product Description
S.A.E. Nomenclature
Metal-Encased Oil Seal Designs
One-Piece Molded Oil Seal Designs
Split Seal Designs
Victor Production Facilities
Victoprene Compounds
Synthetic Rubber Elastomers Chart
Applied Sealology
Peripheral Speeds Chart
O.D. Press Fit Chart
Application Design Features
Installation Data
Oil Seal Application Index
Seal Sizes and Types—by Shaft Diameter
Seal Sizes and Types—by Numerical Listing
Metal-Encased Felt Seal Listing

Compiled Entirely to Serve Specifier's Needs

You'll quickly see this is not just the usual reference catalog that tells you what you can have. Instead, this new, modern edition shows and tells you how to get the oil seal you need —and how to insure effective performance.

60-page working guide

Here you will find all essential data for modern oil seal specification procedure—much of it in useful form for the first time in any catalog. Every section in the contents table offers valuable help toward better shaft sealing.

Note 2 outstanding features:

All sizes and types of Victor designs are grouped by shaft diameter—the primary consideration. A cross section of each design is immediately adjacent for quick reference.

Specific recommendations are given on design adaptability in relation to pressure, temperature, and shaft speed conditions.

Your copy sent on request

The more you use this catalog, the more you will be impressed with the fact of Victor's pre-eminence in the quality oil seal field, both in meeting your standard as well as custom requirements.

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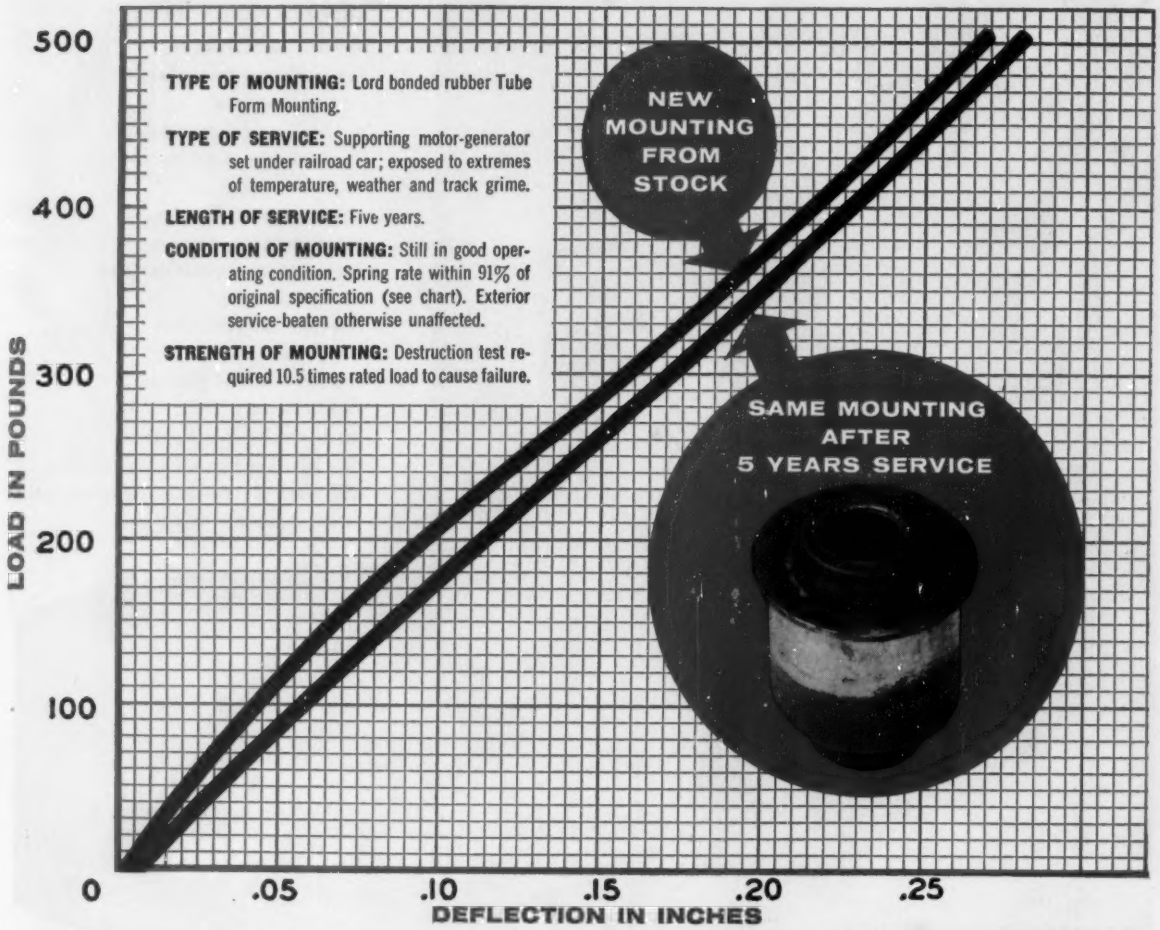
Sealing Products *EXCLUSIVELY*

OIL SEALS • GASKETS • PACKINGS • MECHANICAL SEALS

Circle 454 on page 19

what is the life expectancy of a LORD vibration mounting?


500
400
300
200
100
0
LOAD IN POUNDS
.05
.10
.15
.20
.25
DEFLECTION IN INCHES
TYPE OF MOUNTING: Lord bonded rubber Tube Form Mounting.
TYPE OF SERVICE: Supporting motor-generator set under railroad car; exposed to extremes of temperature, weather and track grime.
LENGTH OF SERVICE: Five years.
CONDITION OF MOUNTING: Still in good operating condition. Spring rate within 91% of original specification (see chart). Exterior service-beaten otherwise unaffected.
STRENGTH OF MOUNTING: Destruction test required 10.5 times rated load to cause failure.
NEW MOUNTING FROM STOCK
SAME MOUNTING AFTER 5 YEARS SERVICE

►*five-year service results in little change in isolation efficiency*

How long do LORD bonded rubber mountings retain their excellent vibration isolation characteristics?

Recently, LORD had an opportunity to test a mounting which had been exposed to five years of rigorous service. The remarkable results shown above are a convincing demonstration of the extra-long life of LORD mountings.

This was not an exceptional case, but is typical of the continuous, long-term effectiveness of all LORD products. It is the planned result of (1) the careful design of the contour of the flexing element to provide uniform stress distribution, (2) a rubber-to-metal bond of unsurpassed strength and permanence and (3) elastomers which are specially selected and custom-compounded for each job. And LORD engineers are constantly striving to build even more life into LORD mountings.

The like-new performance of LORD mountings even after long, rugged service means much in terms of lower lifetime costs, fewer mounting replacements, and greater safety.

When you have a problem in vibration control, it makes sense to bring it to LORD—the leader in engineering vibration control and bonded rubber products. Contact your nearest LORD Field engineer or the Home Office, Erie, Pa.

LORD BONDED RUBBER

designers and producers of bonded rubber products since 1924

LORD MANUFACTURING COMPANY • ERIE, PA.

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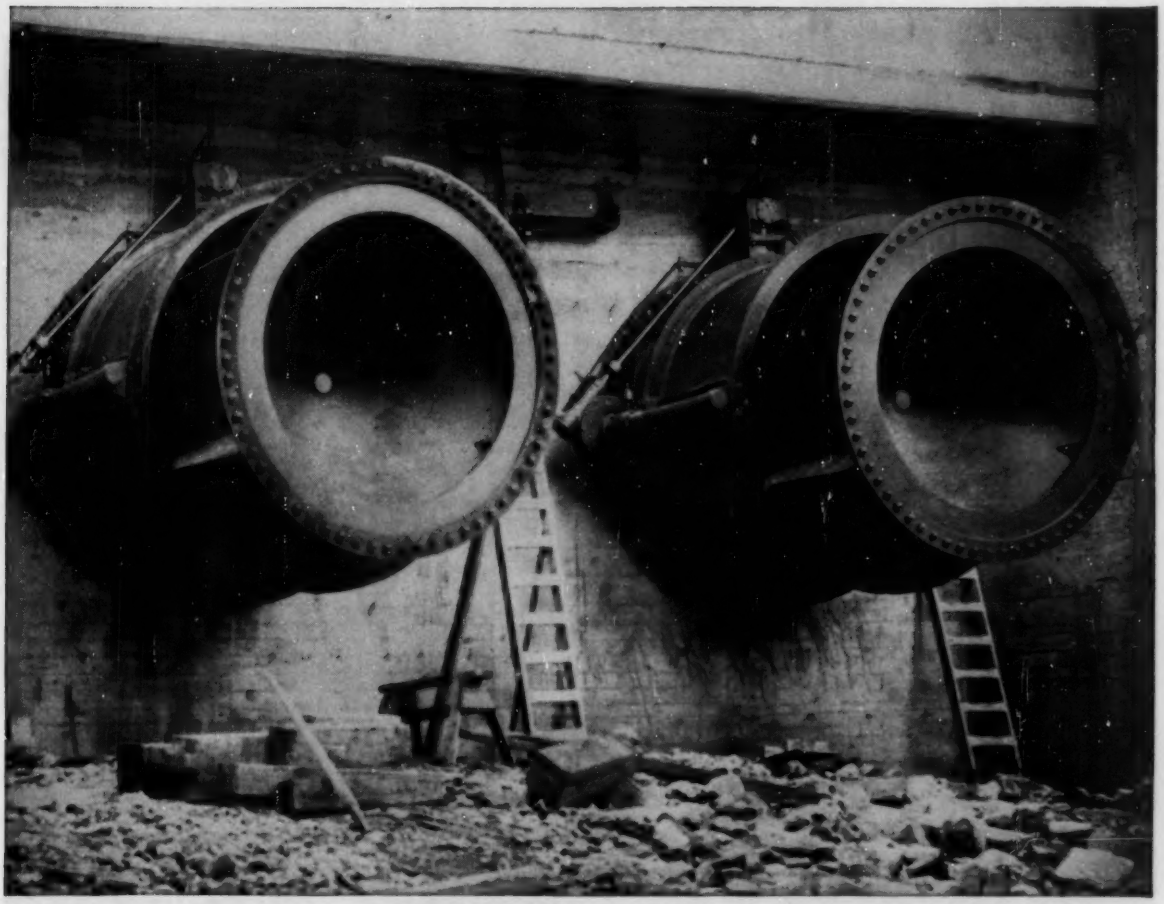
"In Canada—Railway & Power Engineering Corporation Limited"



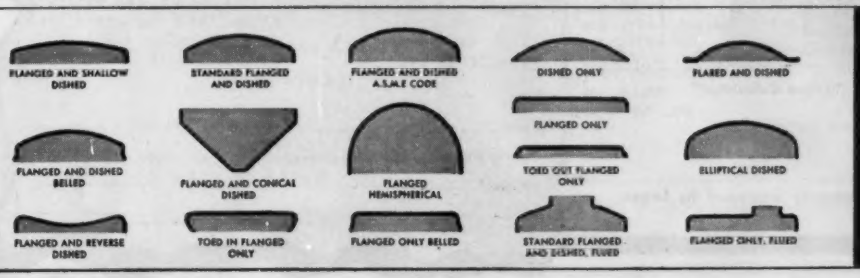
At British Columbia Power Commission's Ladore Dam, 96-inch Howell-Bunger valves dissipate energy from a 75-foot head of free-discharge water. Inverted cones on downstream ends are one-piece Lukens spun heads, a money-saving application.

Amazing what you can do...and save... designing with Lukens Heads

■ Ever think how Lukens standard head shapes might simplify the design of your machinery? Or permit entirely new design? Engineers at S. Morgan Smith, for example, build their huge Howell-Bunger valves using conical Lukens heads at the discharge end. Pre-formed heads reduce design complexity, eliminate costly fabrication steps.

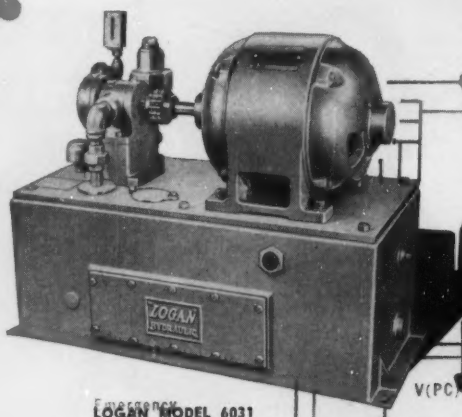
Lukens heads may well improve *your* equipment design, reduce cost. The resources of Lukens' fifty years of leadership in producing heads for many applications are at your service. *Would you like technical details? Write for Catalog 658, "Pricing and Engineering Data", Lukens Steel Company, Coatesville, Pennsylvania.*

Lukens Offers the World's Broadest Line of Spun and Pressed Heads of Carbon, Alloy and Clad Steels



LUKENS ®

Circle 456 on page 19



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FOR POSITIVE, CONTROLLED

POWER

For the simplest or the most complex circuit design . . . Look to Logan. Your one-source manufacturer of dependable hydraulic components to meet your particular need. The assistance of Logan's capable engineering staff is at your service to help you design the circuits to most effectively meet your production problems.

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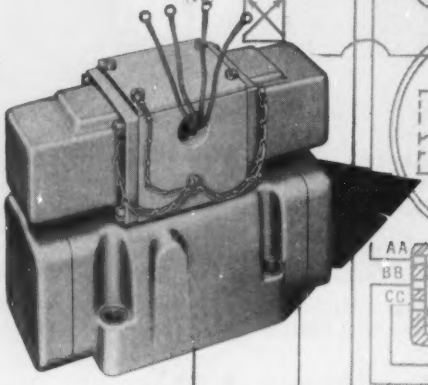
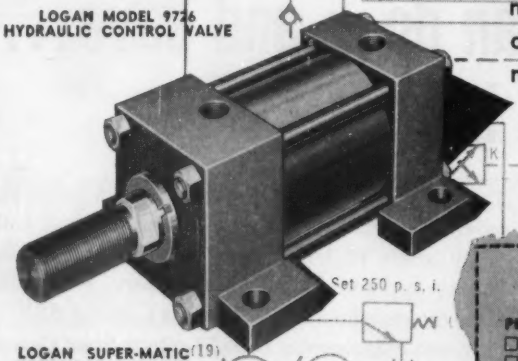


LOGAN MODEL 9726
HYDRAULIC CONTROL VALVE



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HYDRAULIC CYLINDER

FREE! *Send for the "Logan Calculator"*

Properly designed, properly equipped by Logan.

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- ☐ 100-2 MILL-TYPE AIR CYLS.
- ☐ 100-3 AIR-DRAULIC CYLS.
- ☐ 100-4 AIR VALVES
- ☐ 100-5 LOGANSQUARE CYLINDERS
- ☐ 100-5-1 ULTRAMATION CYLINDERS
- ☐ 51 PRESSES
- ☐ FACTS OF LIFE
- ☐ 62 SURE-FLOW PUMPS
- ☐ 200-1 HYD. POWER UNITS
- ☐ 200-2 ROTOCAST HYD. CYLINDERS
- ☐ 200-3 750 SERIES HYD. CYLINDERS
- ☐ 200-4 and 200-7 HYD. VALVES
- ☐ 200-6 SUPER-MATIC CYLS.
- ☐ 70-1 CHUCKS
- ☐ ABC BOOKLET
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TO:

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COMPANY _____

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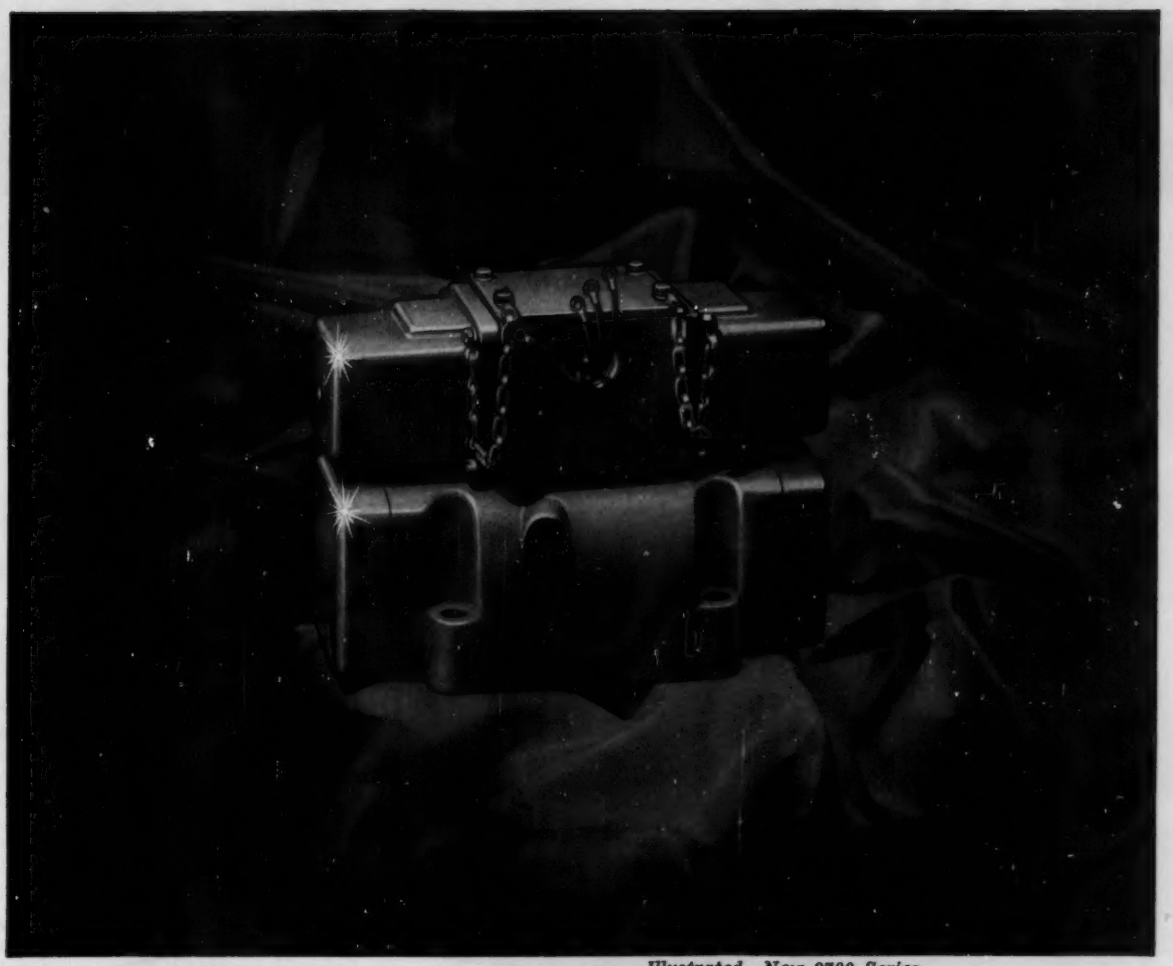

Illustrated—New 9700 Series
Piggy Back Hydraulic Control Valve
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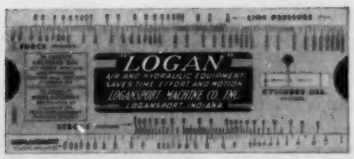
the ultimate in hydraulic valve design



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LOGANSPORT MACHINE CO., INC.
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- ☐ 100-2 MILL-TYPE AIR CYLS.
- ☐ 100-3 AIR-DRAULIC CYLS.
- ☐ 100-4 AIR VALVES
- ☐ 100-5 LOGANSQUARE CYLINDERS
- ☐ 100-5-1 ULTRAMATION CYLINDERS
- ☐ 51 PRESSES
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- ☐ 200-3 750 SERIES HYD. CYLINDERS
- ☐ 200-4 and 200-7 HYD. VALVES
- ☐ 200-6 SUPER-MATIC CYLS.
- ☐ 70-1 CHUCKS
- ☐ ABC BOOKLET
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TO:

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COMPANY _____

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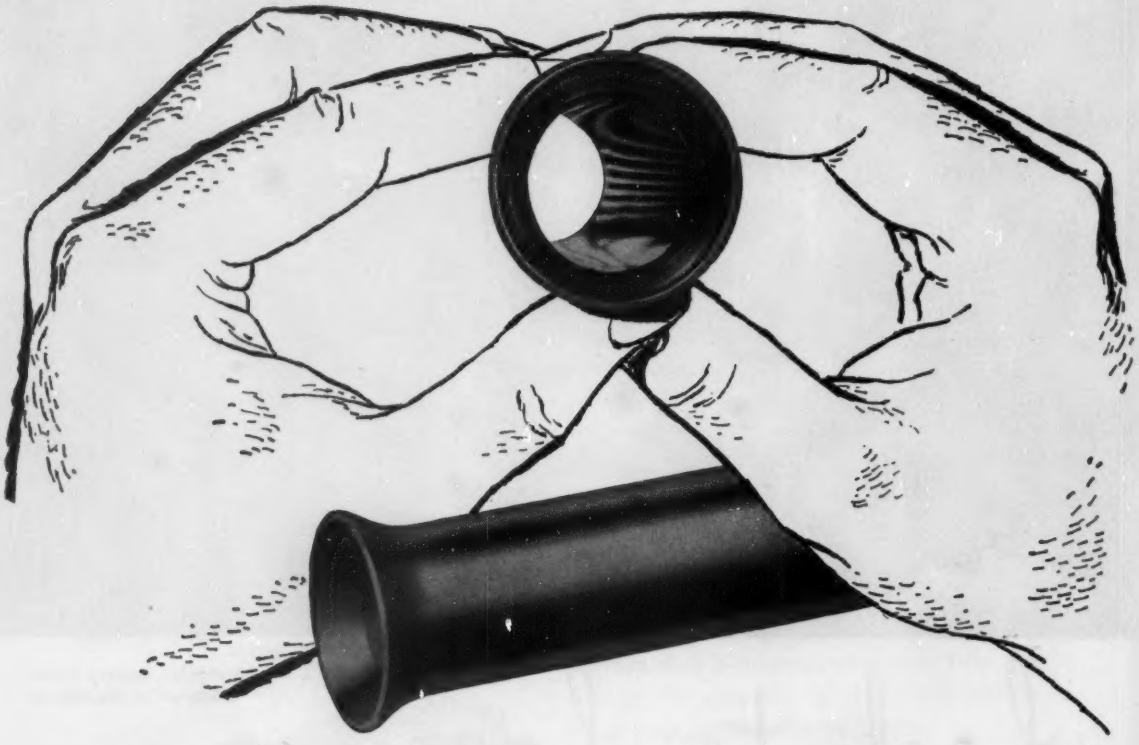
Circle 457 on page 19

Cut Hydraulic Flow Resistance . . . Specify HYDRALUSTER the Only "rifle-barrel" Tubing



AXIOM: The smoother the surface, the less resistance offered. And here you see the inside of a section of HYDRALUSTER tubing . . . photographic proof of a super-smooth surface.

Hydraluster is a cold-reduced, carbon steel tube for hydraulic and diesel application. Its exclusive finish is the reason that systems using Hydraluster are developing the highest rates of power efficiency and reaction time.

Hydraluster has other advantages to offer the Original Equipment Manufacturer. Hydraluster is highly resistant to oxidation, even under the conditions imposed by the newest, high-speed fluids. The result is greatly improved maintenance records. And the bright exterior finish of the tubing adds to the appearance and sales appeal of precision machinery.

Produced in standard hydraulic sizes, Hydraluster is a premium tube sold at standard hydraulic tubing prices.

SAMPLES and SPECIFICATIONS: Make the "rifle-barrel" test yourself. Your name on a company letterhead will bring specifications, literature and a sample of Hydraluster by return mail.

Summerill

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in design

Butterfly valve with sleeve of Hypalon® gives 2 years' perfect service handling strong acids

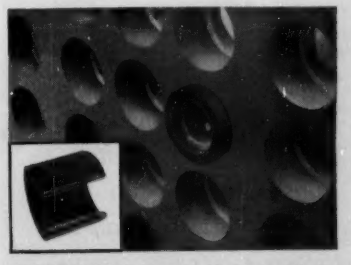
New neoprene grommet design saves $1500/yr. in material and labor costs on HCL heat exchangers

Normally, brass ferrules are used in sealing Karbate heat exchanger tubes at the tube sheet—but overtightening of the ferrules often occurs with resultant cracking of the expensive Karbate sheet. A patch is then necessary, and eventually the entire sheet must be replaced.

A molded neoprene seal, developed by a midwest firm, solved the problem. The seal encloses the end of the Karbate tubing and gaskets it firmly to the tube sheet. Success of the seal depends on the lasting resilience of neoprene for a cushioned, tight fit.

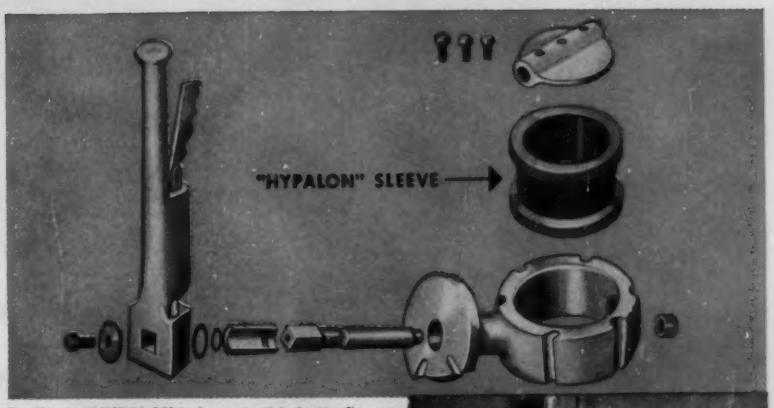
The firm reports 8 years of trouble-free operation with the neoprene seals—an approximate saving of $1,500 a year in material and labor. An unusual story? No. Designers everywhere are taking advantage of neoprene's resistance to acids, heat, abrasion, flex cracking, oil and grease to make better-performing products for industry.

It will pay you to get all the facts about neoprene, Du Pont's all-purpose synthetic rubber. Just mail coupon at right for full information.



NEOPRENE tube-to-tube-sheet seal is inserted with a special hand tool. Neoprene's lasting resilience assures a tight fit without damaging the Karbate, while its acid resistance gives long service.

Circle 459 on page 19



Resilient "HYPALON" sleeve in this butterfly valve snaps into the ring piece. It acts both as a valve seat and as the gasket between the ring piece and mounting flanges, giving a perfect seal.

HYPALON's elasticity and resistance to chemicals contributes to success of valve design

Industrial Wastes, Inc., of Beaver Falls, Pa., hauls about 2½ million gallons of spent sulfuric, nitric, hydrochloric and hydrofluoric acids to their disposal plant by tank truck each month. About two years ago, the company faced the problem of finding an all-purpose tank outlet valve that would give longer service under such severe service conditions.

They tried a specially designed butterfly valve with a sleeve of HYPALON, Du Pont's new synthetic rubber. After two years of constant acid service, the valve is still in operation—an excellent example of HYPALON's chemical resistance.

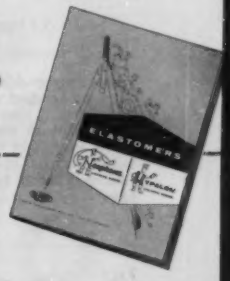
Here's how the valve works: An acid-resistant metal damper rotates in a ring piece lined with a snap-in HYPALON sleeve. This resilient sleeve is slightly smaller in diameter than the metal disk, resulting in a distortion sufficient to assure a pressure-tight seal when the valve is closed.

NO OTHER RESILIENT MATERIAL can match HYPALON for service life on the "tough" jobs in industry. It has unusual resistance to hardening at elevated temperatures (250° to 350°F.) and is virtually unaffected by ozone. HYPALON also offers excellent resistance to abrasion, flame, flex cracking. We'll be glad to tell you more about HYPALON—its properties and applications. Just mail coupon below.

DU PONT
REG. U. S. PAT. OFF.

***HYPALON** is a registered trademark of E. I. du Pont de Nemours & Co. (Inc.)*

BETTER THINGS FOR BETTER LIVING . . . THROUGH CHEMISTRY



☐ I am particularly interested in _____

☐ Please add my name to the mailing list for your free publication, "The Du Pont Elastomers."

Name _____

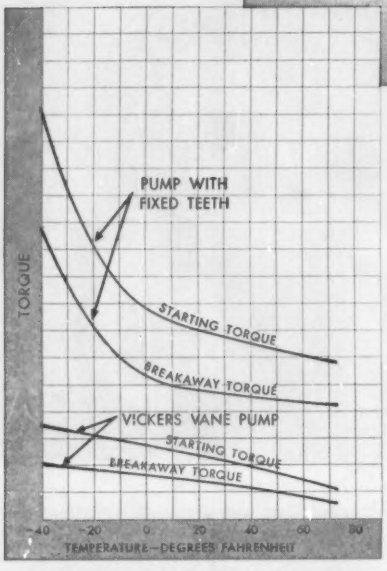
E. I. du Pont de Nemours & Co. (Inc.) *Firm* _____

Elastomer Chemicals Dept. MD-2 *Address* _____

Wilmington 98, Delaware *City* _____ *State* _____

MUCH EASIER COLD WEATHER STARTING

Sno-Cat (without body) undergoing tests in extreme cold in the Pyrenees mountains preparatory to being used by French scientific expedition at the South Pole. Sno-Cats will also be used by the U.S. Navy and British Expeditions to the Antarctic.



Curves based on comparative tests of a Vickers Balanced Vane Type Pump and an equal capacity pump with fixed teeth. Oil used in both was SAE 10W premium grade.

Another Reason Why

TUCKER SNO-CATS have

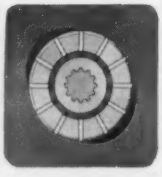
VICKERS® Balanced Vane Pumps

The Sno-Cat operates where it is really cold . . . high in the mountains . . . with U. S. Navy, French and British Expeditions in the bitter wastes of the Antarctic . . . wherever snow is so deep that wheel vehicles fail.

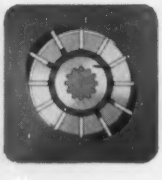
Like many other vehicles that must operate in cold weather, the Sno-Cat uses a Vickers Vane Pump to avoid the extra starting handicap that would be imposed by a hydraulic pump with fixed teeth or spring-extended vanes. In extremely low temperatures such a pump seriously increases starting load over normal (see curves at left) . . . at a time when the cold has substantially reduced the power of the starting battery. The diagrams below at the left show why Vickers Vane Pumps provide much easier cold weather starting.

All Tucker Sno-Cats use a Vickers hydraulic power steering system. In addition to the pump, these systems include a steering booster, a volume control, and overload relief valve.

Any vehicle which must operate in cold weather needs a hydraulic pump that provides "no-load starting". Let us tell you more about it . . . and about the many other reasons for using Vickers Balanced Vane Pumps.



Schematic diagram of Vickers Balanced Vane Type Pump showing how sliding vanes are retracted at normal engine cranking speeds. No oil is pumped and there is practically no starting load.



Similar diagram shows how pump vanes are extended when engine fires. Pumping then begins and continues at all engine speeds (vanes are held in intimate contact with cam ring by system pressure in addition to centrifugal force).

VICKERS INCORPORATED

DIVISION OF SPERRY RAND CORPORATION

ADMINISTRATIVE and ENGINEERING CENTER

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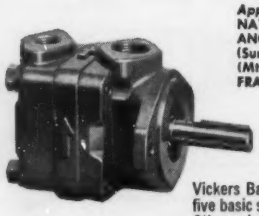
Application Engineering Offices: **• ATLANTA • CHICAGO • CINCINNATI • CLEVELAND • DETROIT • GRAND RAPIDS • HOUSTON • LOS ANGELES AREA (El Segundo) • MINNEAPOLIS • NEW YORK AREA (Summit, N.J.) • PHILADELPHIA AREA (Media) • PITTSBURGH AREA (Mt. Lebanon) • PORTLAND, ORE. • ROCHESTER • ROCKFORD • SAN FRANCISCO AREA (Berkeley) • SEATTLE • ST. LOUIS • TULSA • WASHINGTON • WORCESTER**

IN CANADA: Vickers-Sperry of Canada, Ltd., Toronto



Vickers Balanced Vane Type Pumps for mobile equipment are available in five basic sizes having 15 normal delivery ratings and a variety of mountings. Other advantages include: high efficiency, automatic wear compensation, hydraulic balance, dependability and long life. Write for Catalog M-5101.

ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

7376

Circle 460 on page 19

Wilmington 98, Delaware

City_____ State_____

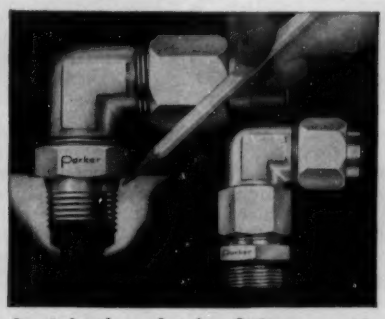
Be sure to see Parker for both tube and hose fittings!

Here, from one convenient source, you can get the most advanced hydraulic fittings available . . . both tube *and* hose. For example, new Parker *no-skive* Hoze-lok fittings require no stripping of rubber-covered hydraulic hose. They're faster, easier to use and *re-usable.*

Also, new Parker *straight-thread* tube fittings solve high-pressure hydraulic leakage problems resulting from tapered pipe threads. *Straight* threads are available on Triple-lok (the industrial standard flare tube fitting) and on Ferulok (flareless fitting for heavy steel tubing).

Parker
Hydraulic and fluid system components

***No-skive* Hoze-lok fittings** need no stripping of hose covers. Only two simple steps complete the make-up. Re-usable.



Straight-thread tube fittings provide leakproof, trouble-free connections. No overtightening. O-ring makes the seal.

TUBE & HOSE FITTINGS DIVISION
Section 422-N
The Parker Appliance Co.
17325 Euclid Ave., Cleveland 12, Ohio

☐ Please send no-skive Hoze-lok Bulletin No. 4402
☐ Straight-thread fittings Catalog No. 4301

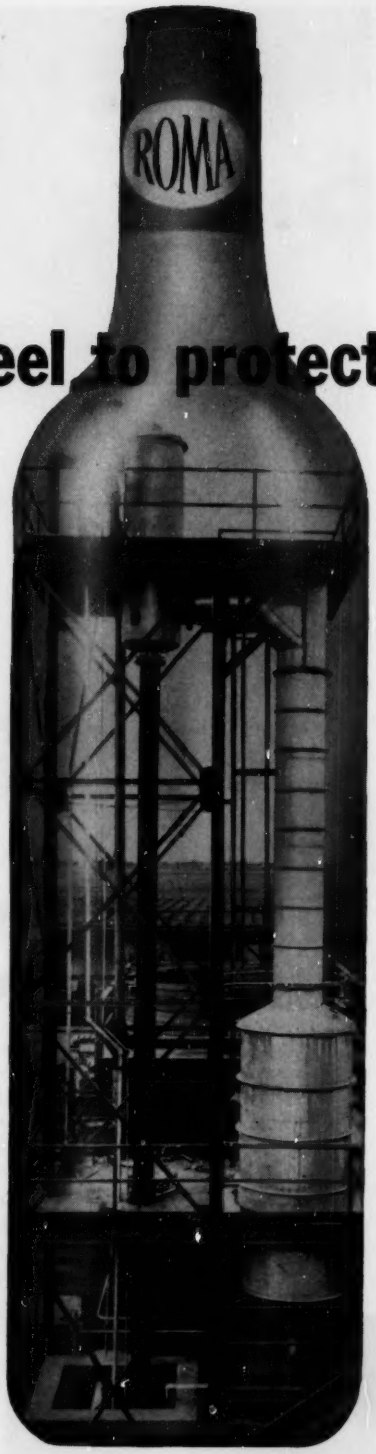
NAME_____

COMPANY_____

ADDRESS_____

CITY_____ STATE_____

Designed with stainless steel to protect product purity



America's largest winery has specified stainless steel in new equipment, as a regular policy to replace old and obsolete installations known to be sources of metal pick-up. This user, The Roma Wine Company, finds prevention far better than the cure. And less costly, too!

Resist Corrosion

Chromium-nickel stainless steels resist attack by chemicals and atmospheres over wide ranges of concentrations, pressures and temperatures.

Prevents Contamination

The inherently hard, smooth surfaces of these austenitic chromium-nickel steels make poor harbors for bacteria or other contaminants.

Easy to Clean

Also, users find stainless steel equipment easy to clean and to *keep hygienically* clean as well as attractive in appearance.

New Stainless Steel Booklet Available

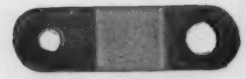
Write for a copy of "Stainless Steel in Product Design." Yours for the asking . . . it tells where and how to use stainless, how to design for lower cost, and other ways to give your products an edge on competition. Write for it now.

Roma Wine Company, a division of Schenley Industries, Inc., makes grape juice concentrate at the rate of 600 gallons per hour in the vacuum pans (above) of chromium-nickel stainless steel. Typical of other stainless equipment used for safeguarding purity of Roma products are pasteurizers, heat exchangers, centrifugal pumps, agitator tanks and wine coolers. All of austenitic chromium-nickel stainless steel.

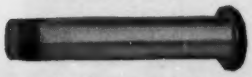
INCO TRADE MARK **THE INTERNATIONAL NICKEL COMPANY, INC.** 67 Wall Street New York 5, N.Y.

"Stress raisers" eliminated by Link-Belt LXS chain design

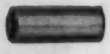
LXS "FULL-ROUND" DESIGN



"Full-round" pitch holes . . . no sharp corners



"Full-round" pin



"Full-round" bushing

"FULL-ROUND" DESIGN eliminates stress concentration points. Heat treatment of all parts adds even greater strength and extra wear life to selected steels. Accurate control of these processes avoids brittleness, poor wear values and low tensile strengths . . . and assures uniformity.

Large pins, bushings mean ample live bearing area for long life

For long life under severe conveyor and drive conditions, Link-Belt LXS chain provides extra strength, increased wear resistance and wider application flexibility. This fabricated steel roller chain incorporates many advanced design and manufacturing refinements, resulting in superior ruggedness and accuracy.

Eliminate weak points

"Full-round" design does away with stress concentration points most frequently subject to failure . . . provides maximum live bearing area between pin, bushing and sidebars. As a result, stress is distributed evenly, increasing chain life.

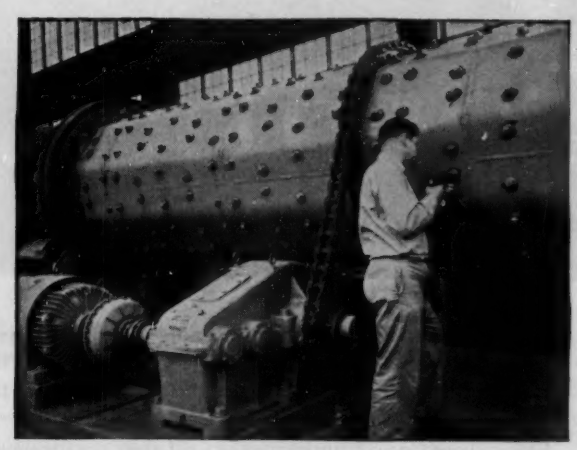
Pins and bushings are accurately sized for controlled press fit, preventing rotation in sidebars. Made from selected bar steel, sidebars are carefully machined for proper pitch hole size and for maintaining firm, tight press fit of pins and bushings. This assures close control of pitch and proper chain length after assembly.

Hardening extends life

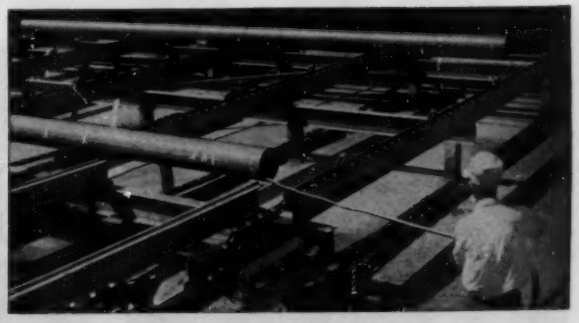
Another Link-Belt long-life extra is the controlled hardening of selected steels used in the manufacture of LXS chain. Pins, for example, are made from a tough steel, specially treated for high strength in shear and for maximum wear value. Bushings are properly hardened to shrug off shock and resist wear.

Rollers are accurately machined to assure proper operating clearances and free-rolling action. Controlled hardening gives them the necessary resiliency and durability.

LXS especially popular for exposed drives, high impacts



Link-Belt LXS chain is the long-life answer for exposed drives, abrasive and high-impact conditions. Its large, live bearing area reduces cutting action of abrasives because load is spread over a broad area.



LXS chain provides extra strength, wear-life for heavy-duty conveying

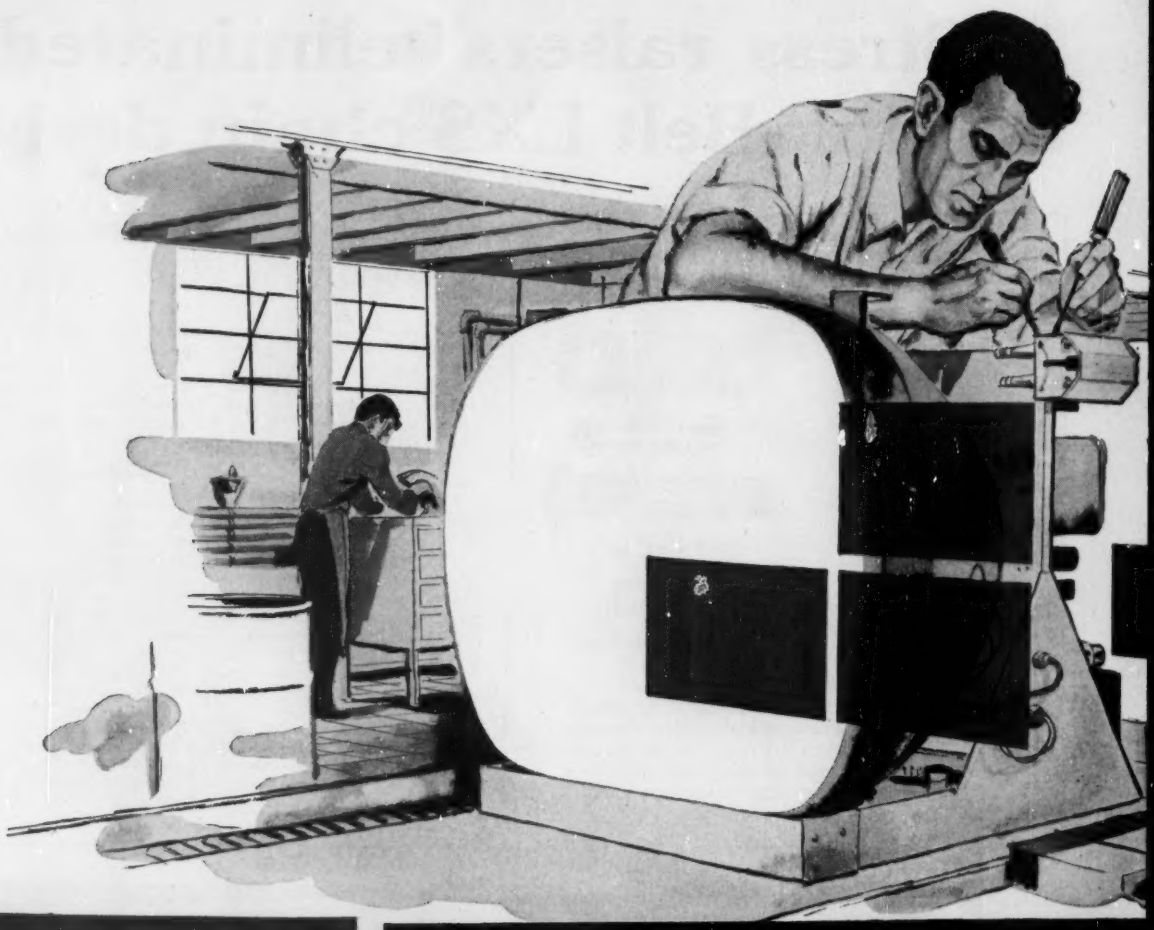
Link-Belt LXS chain has real stamina—as shown in this conveyor application for handling 1000-pound, 40-foot lengths of steel pipe. Thanks to accuracy of pitch and attachment spacing, plus close matching of multiple strands, LXS has the added strength and wear life for the extra-long conveyors so popular in today's move to mechanization.

For help with any chain problem call your nearby Link-Belt office. Send for 342-page catalog 950 covering the complete line of standard Link-Belt products for conveying and power transmission.

LINK-BELT

CHAINS AND SPROCKETS

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 14,250



new Formica

Exceeds NEMA standards for XXP...meets UL requirements for printed circuitry... meets MIL SPEC 3115B for type PBE-P

New Formica Cirprint is far superior to any XXP ever made. The latest product of Formica-4 research, it is the first and only copper clad especially designed to meet the requirements of large volume manufacturers.

Check these Cirprint properties against your requirements:

High IR: 250,000 megohms after 96 hours at 35° C and 90% relative humidity.

Cold punching: up to and including 1/16".

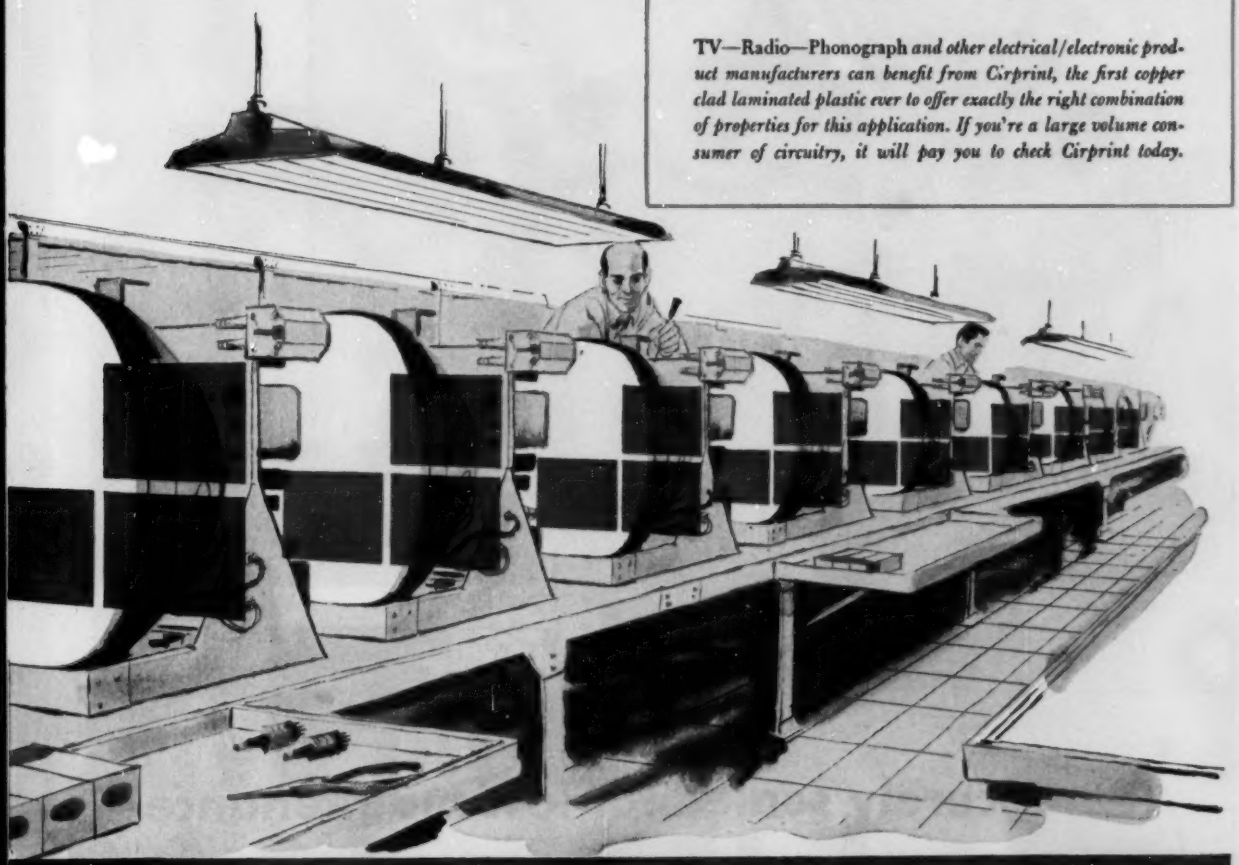
Low moisture absorption: 0.80% in 1" x 3" x 1/16" sample after 24 hours immersion.

subsidiary of CYANAMID

1st choice in laminated plastics

Application engineering • *Fabricating* • *Research*

TV—Radio—Phonograph *and other electrical/electronic product manufacturers can benefit from Cirprint, the first copper clad laminated plastic ever to offer exactly the right combination of properties for this application. If you're a large volume consumer of circuitry, it will pay you to check Cirprint today.*



CIRPRINT

Cirprint watermarking gives you quick, positive, visual identification. Eliminates costly and ineffective factory records and marking systems.

You can *see* the quality because Cirprint is translucent. Its smooth structure is free of all impurities. Translucency also permits a visual check on the register of circuits printed on opposite sides of a sheet.

Enthusiastic reports from manufacturers who have tested Cirprint state it's the best XXP ever made . . . and that its outstanding properties are most useful.

Evaluate the contribution Cirprint can make to your electrical/electronic products. Send today for free bulletin 755. Use the handy coupon below, or write Formica Corporation, subsidiary of American Cyanamid, 4514-7 Spring Grove Ave., Cincinnati 32, Ohio.

Formica Corporation FI-1345
4514-7 Spring Grove Ave., Cincinnati 32, Ohio
Please send me a copy of Cirprint bulletin 755.

Name_____

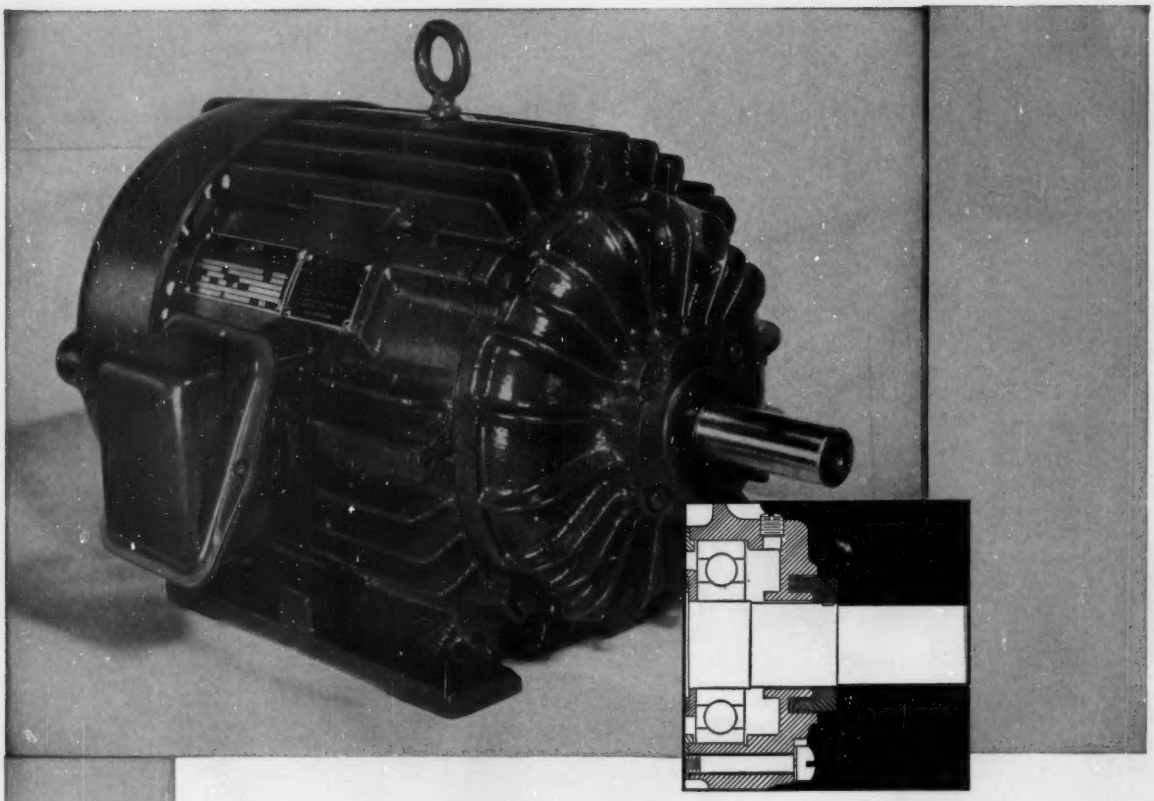
Company_____ Title_____

Address_____

City_____ Zone____ State_____

Customer stock service

Circle 463 on page 19



Securely sealed for low maintenance —

TOTALLY ENCLOSED FAN COOLED MOTORS

Century

When motor maintenance goes down, production goes up. Century TEFC Motor *protects itself* from dust, grit, chemical fumes, moisture. Shaft openings at each end are labyrinth-sealed, and there is a precision clearance between metal seal and bearing bracket.

Outside, a hose or whisk broom quickly cleans it. External fan forces jets of cooling air across the frame. Inside, vital motor parts are completely sealed off from injurious atmosphere. Factory lubrication of bearings is adequate for several years' service under normal conditions; however, whenever required bearings may be relubricated through grease plugs.

For full facts on your specific application, call the Century District Office or Authorized Distributor nearest you.

CENTURY . . . building TEFC Motors for 25 years

CE-66R

Performance-Rated®
MOTORS
1/20 to 400 H.P.

CENTURY ELECTRIC COMPANY

1806 Pine Street • St. Louis 3, Missouri • *Offices and Stock Points in Principal Cities*

Circle 464 on page 19

save money, minutes, metal

with B&W MECHANICAL TUBING

CARBON • ALLOY • STAINLESS

Countless hollow parts and products now being made from solid stock can be fabricated more economically from tubing. The hole is there, eliminating heavy drilling with all its attendant waste. And the wide range of sizes, shapes, analyses, finishes and heat-treated conditions in which B&W Mechanical Tubing is available, make it a semi-finished product in itself — reduce all your machining operations to the minimum.

Get the facts on savings from Mr. Tubes, your link to B&W and your local B&W tubing distributor.

Write for Guide to the Use of Seamless Mechanical Tubing, Technical Bulletin 340.

The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pa.

B&W TUBULAR PRODUCTS DIVISION

Seamless and welded tubular products, seamless welding fittings and forged steel flanges—in carbon, alloy and stainless steels

Circle 465 on page 19

TA-5031 (O)

Grandmother-

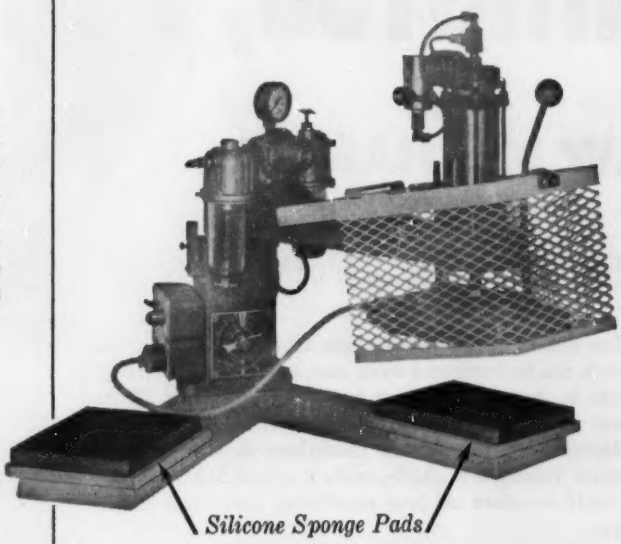
YOUR PATCHING DAYS ARE OVER...

ROTH developed silicone sponge rubber pads solved heat and pressure adhesion problems of commercial patcher

High heat and high pressure are required to melt the adhesive and to make a lasting seal in commercial patches used in the overall and uniform supply industry. An automatic patching machine had been developed for this purpose but production was held up as patches were not getting the proper adhesion . . . particularly over seams and under buttons.

ROTH RUBBER Technical Knowledge and Experience developed a silicone sponge that would withstand the 400°F. temperature required and the 80 pounds per square inch pressure. Not only does a pad of this Roth silicone sponge withstand this pressure and temperature but it retains its resiliency over thousands of patching cycles.

The American Heat Seal Patching Machine, manufactured by American Heat-Seal Inc., Chicago, provides complete safety for the operator and automatically controls time, temperature and pressure for applying "Stay On" patching material. For faster output, two pads of Roth developed silicone sponge are used and the operating arm of the machine is swung from one pad to the other.



IF YOURS IS A PROBLEM IN RUBBER...LET ROTH'S EXPERIENCE WORK FOR YOU

Write for technical data on Roth developed silicone sponge and molded silicone rubber parts

ROTH RUBBER COMPANY Division of Vapor Heating Corporation
1860 South 54th Avenue • Chicago 50

Circle 466 on page 19

6 good reasons why industry prefers

OHMITE®

HIGH CURRENT

ROTARY

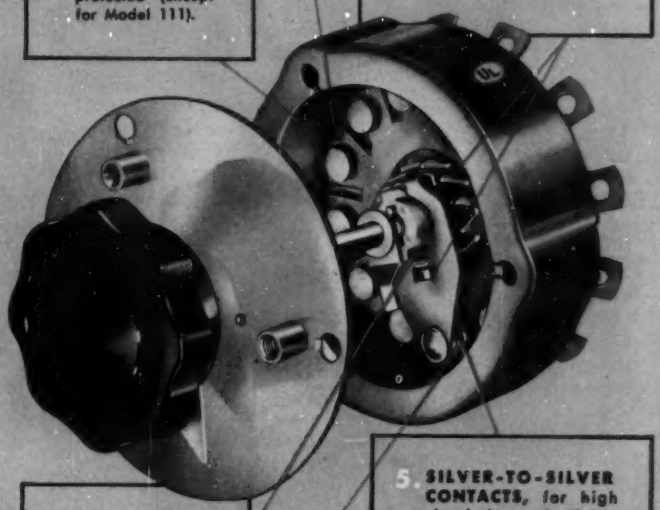
TAP SWITCHES

Check the features at right that make Ohmite tap switches preferred by industry everywhere. Shown below are five sizes of high-amperage, multi-point selectors. They are extremely compact, providing up to 12 tap terminals. In addition to the types and sizes shown, Ohmite tap switches are supplied in open, all-ceramic, shorting and non-shorting types. All Ohmite tap switches can be mounted in tandem for multiple-pole operation.

2. **EXTREMELY COMPACT,** yet have many high-current taps, perfectly insulated. Terminals are convenient for wiring. Back-of-panel mounting.

1. **CERAMIC CONSTRUCTION** provides perfect insulation unaffected by arcing. Contacts and mechanism are entirely enclosed and protected (except for Model 111).

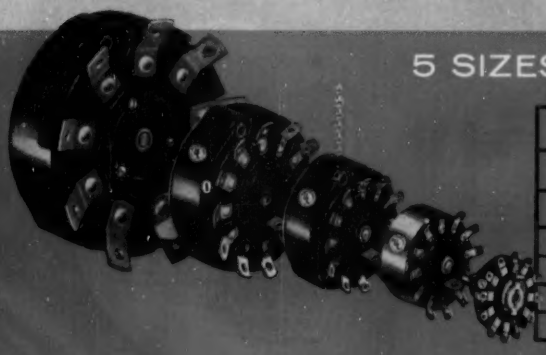
3. **"SLOW-BREAK" MECHANISM,** incorporating a positive cam-and-roller, provides "slow-break, quick-make" action, particularly suited to alternating current. Minimizes sparking, extends contact life.



4. **"DEAD" SWITCH SHAFT.** Completely insulated from the load by a high-strength driving hub which will withstand a 2000-volt test.

5. **SILVER-TO-SILVER CONTACTS,** for high electrical conductivity. Have low surface resistance, and eliminate contact maintenance.

6. **SELF-CLEANING ROTOR CONTACT.** Slightly rounded, assures perfect seating and producing slight rubbing motion with every operation.



5 SIZES: 10, 15, 25, 50, and 100 AMPS

AC RATINGS		
AMP	VOLTS	NO. TAPS
10	150	2 to 11
15	150	2 to 12
25	300*	2 to 12
50	300*	2 to 12
100	300	2 to 8

*150 Volts between taps.

Write on company letterhead for Ohmite Catalog and Engineering Manual No. 40.

OHMITE MANUFACTURING CO.
3618 Howard St., Skokie, Illinois
(Suburb of Chicago)

Circle 467 on page 19

Be Right with **OHMITE®**

RHEOSTATS • RESISTORS • RELAYS • TAP SWITCHES
TANTALUM CAPACITORS

WARNER ELECTRIC CLUTCH COUPLINGS SOLVE HIGH-SPEED RECORDING PROBLEM

Automatic transmission for remotely controlled, recording oscillograph permits speed changes without stopping machine

Here's an example of how designing Warner electric clutch couplings and brakes into the original unit get results that couldn't be obtained any other way. That's the story of the Cathode Ray Oscillograph Recorder for high-frequency phenomena designed and built by William Miller Instrument Company, Pasadena, California.

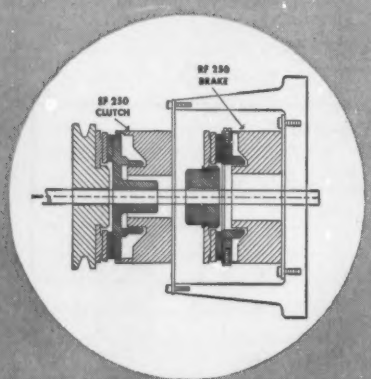
A total of 10 Warner electric clutch couplings and one RF-250 brake are used in the transmission to control recording speeds and in the magazine to control flow of photosensitive recording paper. The Warner clutch couplings in the transmission permit remote pushbutton selection of recording speed ranging between 3 and 400 inches per minute without stopping machine.

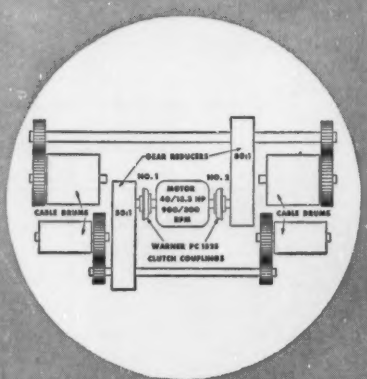
In addition, removing the magazine for darkroom processing of recording paper is also simplified because Warner Clutch-Couplings were incorporated into the original design. All that is necessary is to de-energize the field, unlock the magazine case, and slide the armatures away from their respective fields and rotors.

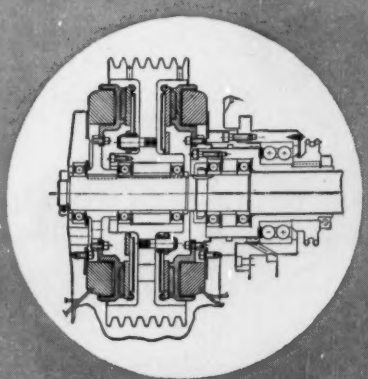
Pushbutton, centralized control that can be custom-designed right into the machine's electrical requirements is yours with Warner Electric Motion Control. Split-second operation and precise control for automatic cycling, indexing, positioning, starting, and stopping guarantee that your machines have the design advances your customers want. Capacities range from 8 in. lb to 700 ft. lb, maximum static torque rating.

Instantaneous shift in recording rate, when required, is pushbutton controlled (above). Removing magazine for darkroom processing of recording paper requires only the de-energizing of two Warner electric clutch couplings, shown at right, and unlocking the magazine.

SOLVE POWER PROBLEMS LIKE THESE QUICKLY, EASILY



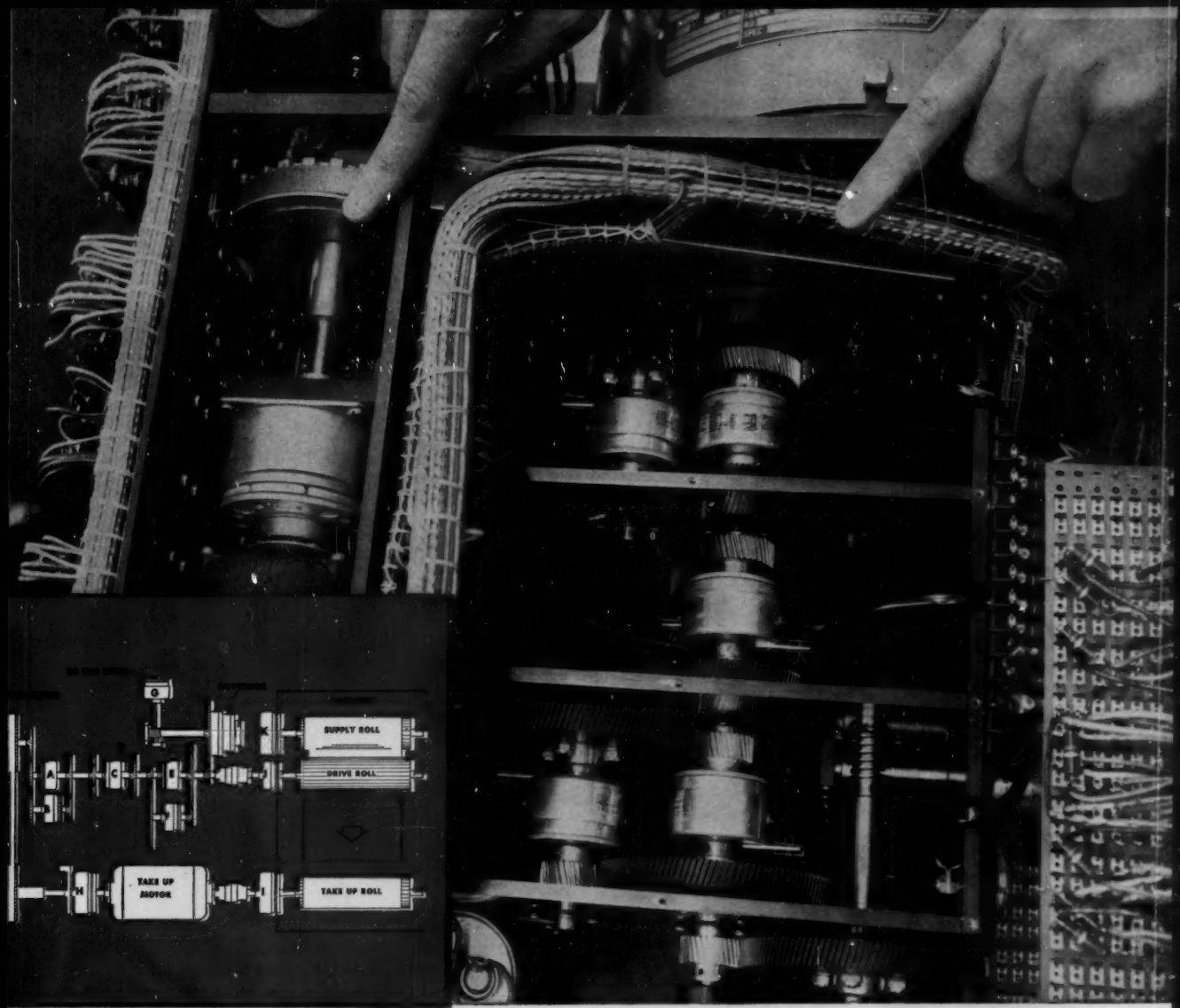




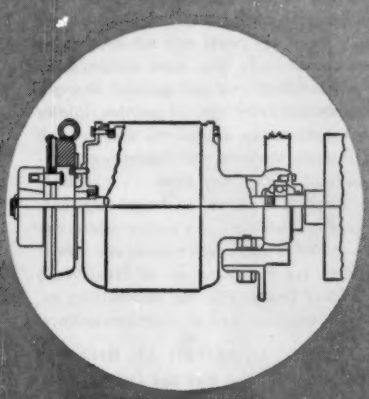
Brake and Clutch on Electronic Computer—electric brake and clutch mounted on the same shaft in sensing and punching unit enable it to handle 100 cards per minute, requiring 6,000 starts and stops per hour. Sensing fingers read data from the punched cards, information goes to computer for solution, and answer is punched onto the card.

Clutch Couplings on Gantry Crane—independent or simultaneous operation of two double drum hoists enables loads up to 25 tons to be handled at either 8 or 24 hook feet per minute, depending on whether 300 or 900 rpm motor winding is energized. Clutch couplings are actuated by pushbutton from the operator's cab, with each handling two drums.

Clutches on Turret Lathe—two electric clutches, plus one constant-running-drive motor belted to a constant-speed drive sheave are all that is needed to stop, start, reverse, or jog turret lathe spindle. Forward clutch is keyed to drive shaft and through gearing to machine spindle. Reverse clutch, keyed to sleeve around drive shaft, drives spindle through chain and gearing.



Ten Warner electric clutch couplings and one electric brake are used in the Miller Oscillograph as shown and in photo diagram above. Six SF-160 clutch couplings (A to F) are used in pairs in each of three sections in the transmission gear train. Section 1, using clutches A and B, provides a 2:1 speed reduction; section 2, using clutches C and D, provides a 4:1 reduction; and section 3, using clutches E and F, provides a 16:1 reduction. Clutch G, coupled to the main drive through a gear set, controls the length of paper to be run for recording. Clutch H couples the main drive to rewind shaft when a high recording rate requires faster acceleration of take-up roll rotation than is possible with small rewind motor alone. Two clutch couplings (I and J) are used to couple main drive shaft and take-up shaft to their respective rolls. Brake K stops the supply roll and keeps it from unwinding when machine power is cut off by the governor.



Brake on Textile Machine—brake magnet is stationary-mounted to motor housing. Armature is mounted on drive pins to hub, which is keyed to a shaft driving the brush roll. Perfectly synchronized stopping of eight rolls is accomplished by adjustment of individual rheostats in the control panel. Tearing and piling of material between rolls have been eliminated while stopping the machine.

Circle 468 on page 19

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MACHINE DESIGN
FEBRUARY 21, 1957

Play Ball!

IN the absence of a reliable crystal ball, accurate prediction of development engineering costs is a perplexing problem. But so is the prediction, at the beginning of the season, of a ball team's ultimate standing in the league. Both present many uncertainties.

Both situations, like others subject to the laws of probability, lend themselves to intelligent guesswork through statistical analysis—playing the percentages. In his article beginning overleaf, Peter Martino shows how to establish a rational basis for predicting development cost and how to estimate the probable magnitude of uncertainty.

But there is another important factor. As every fan knows, the management of a ball team goes to very great lengths to eliminate uncertainties in the local team. Professional players are selected with great care, hired at fabulous expense and integrated into a harmonious team whose high morale is carefully nursed. And they are used strictly for playing ball—others are hired to do the nonprofessional chores.

Principles of good engineering teamwork are no different—though salaries may be! And it should be no more than common sense, before applying mathematical cost prediction techniques, to eliminate first any uncertainties as to the probable performance of the "home team."

The consequences of failure to do what any club manager worth his salt knows should be obvious to engineering management. Just one consequence alone — high turnover — has played havoc with some of the most careful cost estimates that man and mathematics can produce.

Engineers for their part might well ponder another parallel with the sports world. A ball player is treated with respect not because he goes around calling himself a professional man. He earns it by delivering professional performance.

Play ball!

Colin Carmichael

EDITOR

Predicting

Product Development Costs

. . . from basic idea to prototype model

Predicting beforehand the costs of engineering projects and programs requires more than ordinary estimating techniques. For such analyses, a powerful and effective aid is offered by the methods of statistical analysis.

Application of these techniques in the formulation of an estimating system for accurately forecasting the costs of product development projects is the subject of this article. Methods presented here offer not only a rational basis for cost predictions but also provide a reliable procedure for measuring the accuracy of results.

FROM a financial viewpoint, when a fixed-price development contract is being sought by an engineering organization, management is vitally interested in the most accurate prediction of what the project will probably cost. After evaluation of any competitor's position and their own company's interest in acquiring the contract, management can decide whether or not to submit a bid value lower than the probable final cost, with the resultant overrun or, as it actually is, investment planned for well in advance.

This argument holds equally true in decisions on outlays for internally sponsored programs for developing proprietary items. From a more specific viewpoint, establishing a formal estimating system is necessary to reach decisions on: (1) schedules for workloads and for the hiring of new employees; (2) facilities expansion programs; (3) material procurement programs; (4) operating and capital budgets; (5) overhead rates; and (6) other planning and control functions intimately related with effective operation.

These functions are allied in that they help line personnel perform their duties better. This fact has been recognized in many engineering organizations by having a centralized planning function vested in some unit reporting to the director of engineering.

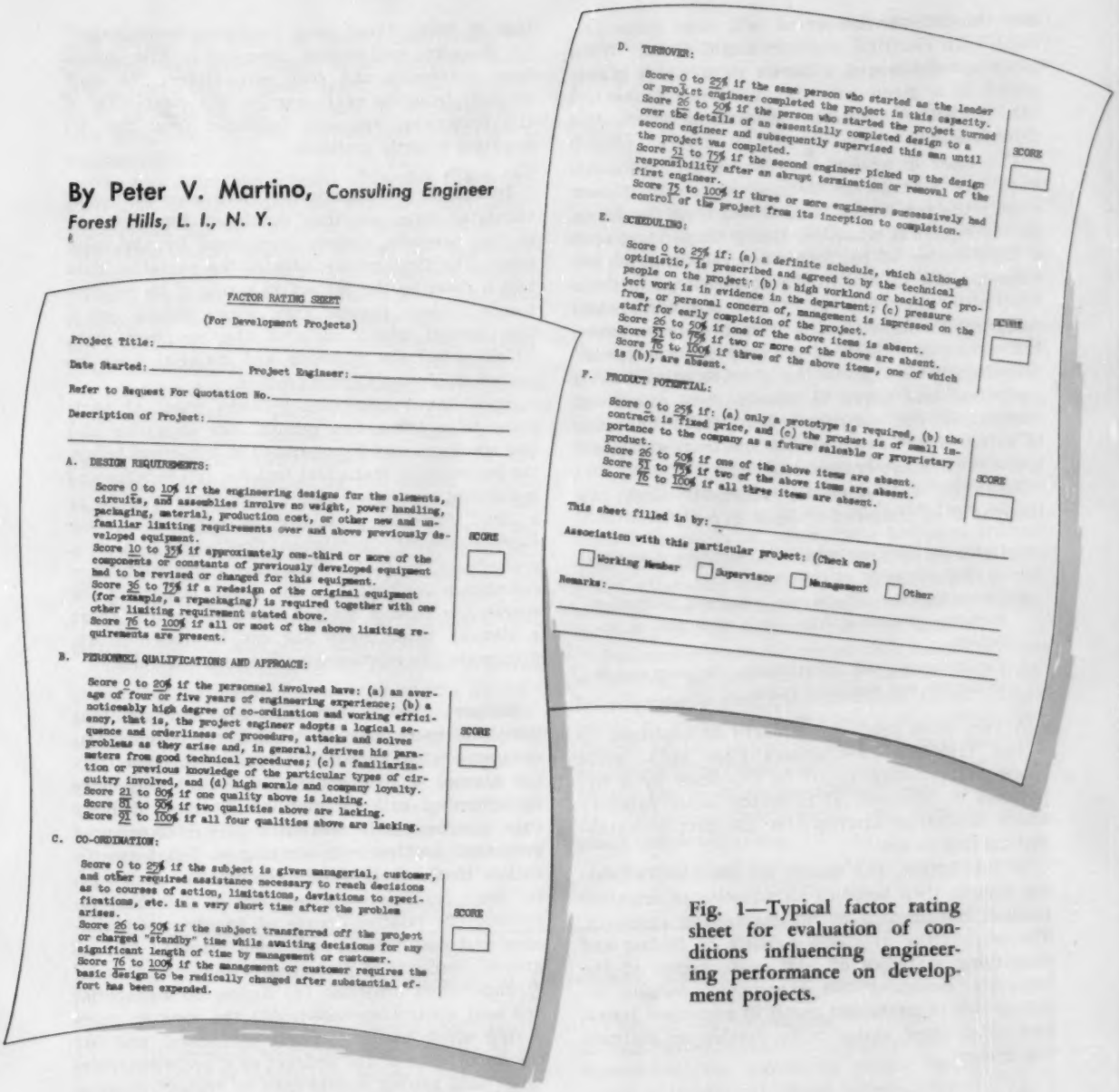
Yardsticks: One difficulty of accurate estimating is in determining which characteristics of the development should be used as yardsticks. That is, can the number of tubes in a radar set be multiplied by a factor to best determine the probable total cost of a given development project? Or, would gross weight indicated on the design specifications be more useful in cost calculations? A perhaps more fundamental question to be answered is whether *any* yardstick can adequately anticipate the ultimate development cost.

The choice of the best yardstick (the causative, independent, or X variable as it will be referred to later) is conditioned by its availability for accurate measurement at the time the proposal is prepared, its correlation to total cost, and the intuitive probability of its affecting the total cost of the project.

As a matter of principle, it is felt that estimates should be made by the people actually responsible for performance. However, if these people have no formal method or do not rely on a common storehouse of information, the worth of the individual's estimate is limited by the merits of his intuitive and subjective skills. Estimating techniques, such as are developed here, can be offered to each project manager as a service for him to use, unless he advocates a more refined approach, or can be adopted as the guiding rule of some centralized department within the organization responsible for checking and screening estimates for quotations.

This article will be divided into two phases.

By Peter V. Martino, *Consulting Engineer*
Forest Hills, L. I., N. Y.



FACTOR RATING SHEET

(For Development Projects)

Project Title: _____

Date Started: _____ Project Engineer: _____

Refer to Request For Quotation No. _____

Description of Project: _____

A. DESIGN REQUIREMENTS:

Score 0 to 10% if the engineering designs for the elements, circuits, and assemblies involve no weight, power handling, packaging, material, production cost, or other new and unfamiliar limiting requirements over and above previously developed equipment.
Score 10 to 35% if approximately one-third or more of the components or constants of previously developed equipment had to be revised or changed for this equipment.
Score 36 to 75% if a redesign of the original equipment (for example, a repackaging) is required together with one other limiting requirement stated above.
Score 76 to 100% if all or most of the above limiting requirements are present.

SCORE

B. PERSONNEL QUALIFICATIONS AND APPROACH:

Score 0 to 20% if the personnel involved have: (a) an average of four or five years of engineering experience; (b) a noticeably high degree of co-ordination and working efficiency, that is, the project engineer adopts a logical sequence and orderliness of procedure, attacks and solves problems as they arise and, in general, derives his parameters from good technical procedures; (c) a familiarization or previous knowledge of the particular types of circuitry involved, and (d) high morale and company loyalty.
Score 21 to 80% if one quality above is lacking.
Score 81 to 90% if two qualities above are lacking.
Score 91 to 100% if all four qualities above are lacking.

SCORE

C. CO-ORDINATION:

Score 0 to 25% if the subject is given managerial, customer, and other required assistance necessary to reach decisions as to courses of action, limitations, deviations to specifications, etc. in a very short time after the problem arises.
Score 26 to 50% if the subject transferred off the project or charged "standby" time while awaiting decisions for any significant length of time by management or customer.
Score 76 to 100% if the management or customer requires the basic design to be radically changed after substantial effort has been expended.

SCORE

D. TURNOVER:

Score 0 to 25% if the same person who started as the leader or project engineer completed the project in this capacity.
Score 26 to 50% if the person who started the project turned over the details of an essentially completed design to a second engineer and subsequently supervised this man until the project was completed.
Score 51 to 75% if the second engineer picked up the design responsibility after an abrupt termination or removal of the first engineer.
Score 76 to 100% if three or more engineers successively had control of the project from its inception to completion.

SCORE

E. SCHEDULING:

Score 0 to 25% if: (a) a definite schedule, which although optimistic, is prescribed and agreed to by the technical people on the project; (b) a high workload or backlog of project work is in evidence in the department; (c) pressure from, or personal concern of, management is impressed on the staff for early completion of the project.
Score 26 to 50% if one of the above items is absent.
Score 51 to 75% if two or more of the above are absent.
Score 76 to 100% if three of the above items, one of which is (b), are absent.

SCORE

F. PRODUCT POTENTIAL:

Score 0 to 25% if: (a) only a prototype is required, (b) the contract is fixed price, and (c) the product is of small importance to the company as a future saleable or proprietary product.
Score 26 to 50% if one of the above items are absent.
Score 51 to 75% if two of the above items are absent.
Score 76 to 100% if all three items are absent.

SCORE

This sheet filled in by: _____

Association with this particular project: (Check one)

☐ Working Member ☐ Supervisor ☐ Management ☐ Other

Remarks: _____

Fig. 1—Typical factor rating sheet for evaluation of conditions influencing engineering performance on development projects.

Initial attention will be given to the theory and fundamental considerations in the design of an experiment and the development of an estimating system. Then, a specific case history will be studied to illustrate application of principles, including all of the steps involved in analyzing operations, recording facts, reducing the data and, finally, determining a set of estimating equations.

Theory of Estimating

The Scientific Method: Estimating might be thought of as the reliable prediction of one variable from the value of another.

Any engineer is familiar with the general phenomenon known as cause and effect (or result). A structural analyst might state: "When given a piece of material of a known modulus which is subjected to a given stress (cause), I can pre-

dict the deformation which will take place (result)." An electrical engineer might state: "When given a resistance of a known value which is subjected to a given potential difference (cause), I can predict the amount of current which will flow (result)."

The basic difference between an art and a science can perhaps be defined in terms of how closely the result can be predicted from the cause. In the electrical situation, Georg Ohm found such a high degree of predictive accuracy that he advanced a law to explain the phenomenon. In fields covered by the word "art," there is a much wider range of results stemming from a common cause. For example, if each of a group of management consultants were given the prospectus of an organization and asked to submit their considered estimate of the company's net worth, the range of values might cover a wide spectrum above and below the average or mean value.

Basically, the scientific approach might be thought of as composed of three steps:

1. Gathering and analyzing the causative elements in each situation or reaction.
2. Recording the effects (or resultant factor or factors) stemming from each situation or reaction.
3. Determining the relationship between each causative and resultant factor.

A very close relationship might be explained by a law (Hooke's Law, Ohm's Law, etc.), while looser relationships might be explained by a hypothesis or principle. It is in the latter category where statistical inference is the proper mathematical tool to use.

In this article, the search for the best estimating system then becomes an adoption of scientific method implemented by an engineering approach. The engineering approach consists of finding and classifying statistics of past performance of the company, designing the experiment, seeking relationships of cause and result in numerical terms, and using these statistics to develop an estimating system.

Fact Finding: This operation consists of determining the really fundamental causative elements involved in a project. This can best be accomplished from a study of past performance as manifesting itself in the records of completed projects. In an electronic-type project, the causative elements to be examined are the number of tubes, chassis area, complexity of circuitry, etc. In an aircraft-type project, say a guided missile exclusive of the electronics, the causative elements to be examined would include weight, skin area, number of mechanical and hydraulic assemblies, etc.

The main idea is to tabulate and classify for each type of project all the pertinent characteristics which might be the cause for the amount of engineering involved and by which future projects can also be estimated. The end result is to select the best pertinent characteristics of the particular type project handled, with the intention of using these as a "common denominator" to measure engineering complexity. The actual final manhours and cost expenditures for each project, from its very start to the completion of the prototype, are also tabulated from the accounting records available.

Design of the Experiment: Two main groups of tabulated data are thus developed for each one of the projects already performed by the company. The first group includes the causative data which describe the project in terms of its requirements (tubes, chassis area, gross weight, etc.). The second group includes the resultant data which reveal the manhour and material costs incurred to develop a given product.

Since the relationship between pairs of variables from these two groups, one causative and one resultant, can be expressed in numerical terms, the appropriate statistical tool for determining and measuring the relationship and expressing it in a brief formula is known as correlation. (see *Significance of Correlation Coefficient.*) A step preliminary to the mathematical calculation of a correlation coefficient is the visual inspection for correlation from a scatter chart. From this chart a visually fitted mean line can be drawn to approximate the relationships between variables.

Factors: Besides the causative and resultant variables, there may be other fairly obvious reasons why a particular development deviated from the normal. For example, one project may have been harried with an inordinately short delivery date, another performed with very inexperienced personnel, another with a stringent design specification. Useful factors to be recorded for each project are: (1) relative experience of personnel involved; (2) relative degree of supervisory assistance and customer co-ordination present; (3) degree of similarity of project as a whole to previously undertaken projects; (4) degree of managerial and cost control exercised; (5) the year or years during which the project was performed; and (6) the importance of the product as a proprietary article. Each project should then be "rated" by some person or persons familiar with its history so that a numerical value for each factor is obtained.

A typical rating sheet is shown in Fig. 1. It is not initially evident whether any or all of these factors have any bearing on the ultimate results, but they must all be tested until they are proven useful or useless.

The commonly accepted tests for this proof are either simple or multiple correlation analyses, or more sophisticated techniques such as multiple factor analyses, randomized or latin squares, or others. The purpose is to determine whether a particular factor explains any of the deviation of specific points from the estimating equation line and if so, its quantitative contribution.

Reports of Actual Performance: Cost accounting systems are primarily designed for cost allocation of specific items, as they occur, to the cor-

rect project. By means of weekly time cards, engineering and other direct labor personnel indicate the number of hours spent on each project, while requisitions for purchase of materials are also designated by the projects for which they are intended.

The accounting department computes the direct labor cost of the hours, the overhead rate (usually applied against projects in proportion to direct labor costs) and the allocation of sundry charges (usually applied proportionately among projects according to standard practices). The data recorded and reported are essentially those required for accurate estimating, but usually modifications to the accounting method of reporting are required.

Data for estimating should be easily extractable from records which segregate costs for application of direct labor manhours and material purchases by *organizational units* for each of the basic *functions* performed in the course of normal operation. In a development-engineering activity, for example, the *organizational units* may be: engineering and design, drafting, model shop, and technical manuals departments. Basic *functions* for the engineering and design department might be: systems planning, component arrangement and testing, systems debugging, and testing.

The proper classification of costs, as oriented above, can be accomplished by initiating an "assignment" for each piece of work by an organizational unit for a basic function, and by collecting and reporting costs against each assignment. In this way, if a more gross analysis of costs is desired at any time, any number of assignments can be grouped together. However, if assignments were not used and an analysis in more detail than recorded by the accounting department were required, it would be virtually impossible to obtain.

Feedback of Results and Control: When an estimating system is adopted, it is part of its installation to devise checks and balances to measure its effectiveness. When an estimate is generated from the estimating system, it is essential that the actual performance of the project be watched, and final results measured against the estimate. Variances between estimated and actual are fed back to the estimator who in turn either redesigns or adjusts the system if faulty, or continues with the system "as is" if found satisfactory. The feedback of error signals in a closed-loop servomechanism is too analogous not to mention here.

Several practical methods of reviewing results are available. The most direct is to make a compilation of all estimates using the estimating system, wait until several projects are completed, and then compare the estimates with the final actual values. However, in our modern technical civilization, the emergence of a prototype two to five years after the start of the development is not unusual. Very few organizations would be willing to wait this long to prove out their system.

This requirement for review then takes the form of setting up and measuring limited objectives. In a properly designed estimating system, there would be a minimum of three points before "delivery" of the prototype at which cost measurements could be taken and compared against an estimate for performance through each stage. In an electronics development, for example, these check points might be:

1. Release of all systems and functional schematic

Significance of Correlation Coefficient

A basic tool of statistical analysis, the correlation coefficient is a measure of the degree of association between two variable quantities. In more practical terms, it provides an indication of how closely the actual values of two variables correspond to a specific theoretical relationship. For convenience, a linear relationship is usually employed as the basis of measurement, although other forms can be, and sometimes are, used.

Values of the correlation coefficient range from a maximum of one to a minimum of zero. If an exact linear relationship exists between values of two variables, the coefficient value is one. As the values of the variables deviate, or "scatter," more and more from a linear relationship, the value of the correlation coefficient decreases, finally reaching a value of zero at completely random association.

Thus, if the correlation coefficient has a high value, indicating a high degree of association, the scatter of actual values about a theoretical (least squares) average or mean line will be confined to a narrow band. Predictive accuracy of the theoretical relationship in such cases for forecasting the values of one variable from the other will be correspondingly high. The smaller the value of the correlation coefficient, the greater the scatter of values for the variables and the lower will be the predictive accuracy of the "estimating equation."

This brief analysis of the correlation coefficient has been limited only to the most fundamental considerations. A complete discussion of this concept and its application in statistical computations can be found in almost any basic textbook on statistical methods.

drawings and specifications.

2. Release of 99 per cent of all the detail drawings for fabrication to the model shop.
3. Physical assembly of all components into a system prior to system debugging or testing.

This "taking-a-pulse" at several points during a development project can reduce the time necessary to prove out the estimating system to a more satisfactory time period. A second, and very important, use of these check points is to give preliminary warning of a trend for a project to be "out of control", perhaps indicating the possibility of a higher or lower overrun than initially planned.

Human Aspect: Since individuals and their personalities are being dealt with, the procedures compromising the estimating system, before being chosen, should be considered from the viewpoint of the ultimate users and, if possible, co-ordinated with them. The harmonious combination of the results required with the reactions of the individuals concerned is the essential feature of a properly co-ordinated situation.

Application of Principles

Concepts outlined in the foregoing section offer a general basis for development of a practical estimating system. Details of their application to specific development projects are illustrated in the following "case history."

Company Data: A hypothetical organization specializes in the engineering development of radar systems. It has technical personnel who, in general, possessed good initial experience and have grown with the organization which is itself only several years old. Through its early efforts and successful performance on a few initial research and development contracts, it has become established in the field and has recently completed several relatively large and complex development contracts.

The organization's accounting department maintains a cost charge system which satisfies customer requirements (primarily the government) and is adequate for financial review. However, the cost charge system does very little in helping management to estimate the cost breakdowns on quotations for current proposals. Most projects were previously awarded to the organization on a "cost-plus-fixed-fee" basis, but due to the pressure of competition and customer requirements, the company is being requested more and more to submit fixed-price proposals.

As a result it has been decided that the function of cost estimating should be refined. Toward this end, the company commissions a staff assistant—an engineer with a statistical background—with the task of developing estimating equations for checking proposal costs. Other information desired from the analysis is (1) an indication of the probable accuracy of values obtained from the estimating equations and (2) specific recommendations on those factors which influence the costs of development projects.

The company has completed development efforts on eight major pieces of equipment, designated here as Projects *A* through *H*. These projects will

Table 1—Major Dependent Variables

Variable	Cost Item
Y_{24}	Total manhours expended by engineering-design department ($Y_{20} + Y_{21} + Y_{22} + Y_{23}$).
Y_{25}	Total manhours expended by drafting department.
Y_{26}	Total manhours expended by engineering-design and drafting departments ($Y_{24} + Y_{25}$).
Y_{27}	Total manhours expended by technician staff.
Y_{28}	Total manhours expended by technical publications department.
Y_{29}	Total manhours expended by model shop department.
Y_{30}	Total dollars spent for material purchases for prototype by model shop department.
Y_{31}	Total dollars spent for material purchases and experimental components by engineering-design department.
Y_{32}	Total dollars project cost.
Y_{33}	Total manhours by *all* of the foregoing organizational units ($Y_{26} + Y_{27} + Y_{28} + Y_{29}$).

Table 2—Subdivision of Dependent Variable for Engineering-Design Department by Function

Variable	Function	Cost Item
Y_{20}	System engineering	Effort in manhours to prepare all functional and block diagrams and to coordinate all development work by planning on a system level.
Y_{21}	Element engineering	Effort in manhours to package, layout and engineer all of the "black boxes" comprising the system.
Y_{22}	Element test	Effort in manhours to test all of the black boxes prior to their interconnection as a system.
Y_{23}	System test	Effort in manhours required to test, modify or rework and retest the black boxes to function as an integrated system.

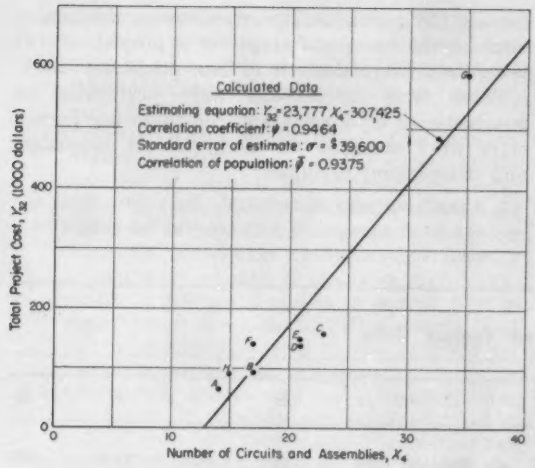


Fig. 2—Simple linear correlation of two variables, X_4 and Y_{32}, based on 8 samples of data given in Table 4. Straight-line plot of estimating equation represents average or mean curve for data as determined by conventional "lease-squares" method of statistical analysis. Letters at different points identify individual projects. Relatively narrow "scatter" of points about line is reflected by the high value of the correlation coeffiicent.

furnish the statistical data for all calculations and conclusions following.

Dependent Variables: As each project reached that point in time where the prototype awaited shipment to the customer, a series of Y or dependent variables were obtained from cost accounting records. These variables are given in Table 1.

The total for the engineering-design department, Y_{24}, was subdivided into the four major pulses of effort found to be inherent in all the projects studied, Table 2.

Total project cost Y_{32} was determined by pricing out, at the prevailing direct labor and overhead rates, all manhours expended on the project and adding all costs incurred for material, Y_{30} and Y_{31}.

Independent Variables: Each completed project was examined after its completion and all measurable physical characteristics of the prototype were recorded as defined in Table 3. The values for these independent variables for each project were obtained from manufacturing drawings, operating manuals, parts lists, examination of the equipment itself, specifications, and internal reports.

Table 3—Independent Variables

Variable	Characteristic	Definition
X_1	Functions	Sum total of any circuit, network, mechanical assembly, or combination of same which produces a major function or result in the system and the absence of which would either physically alter the objective of the system or cause a marked change in operation. If a circuit serves to accomplish two or more independent purposes (i.e., transmission of several frequencies, or indication of results on both audio, visual and graphic devices), it is assumed to have that increased number of functions.
X_2	Circuits	Sum total of all electronic circuits or networks which modify, or are associated with, the system. Typical circuits include: power amplifiers, low-voltage amplifiers, servo power supplies, shaping circuits, range-rate circuits, etc.
X_3	Assemblies	Sum total of mechanical or electromechanical assemblies contained in the system. This includes any one-piece casting of intricate design, such as a console control panel, gear train, and other physical assemblies.
X_4	Circuits & assemblies	Numerical sum of X_2 and X_3 for the particular system.
X_5	Tubes	Sum total of all tubes. Each vacuum tube included in the system is counted with equal weight regardless of the elements within its envelope. Any equivalent of a vacuum tube, such as a transistor, was also counted in the total.
X_6	Components	Sum total of all electronic or mechanical components or devices which are contained in the system. This inciudes all tubes, transformers, meters, relays, inductors, capacitors, gear trains, and any other items having a mounting area requirement of at least 10 sq in., or a volume of at least 30 cu in.
X_7	Chassis area	Total area, sq in., of all chassis and shelves on which components have been or might have been placed.
X_8	Antenna weight	Weight, lb, of the radiating and receiving portion of the system, including all mounting flanges, hardware, interconnecting cables and radomes.
X_9	Equipment weight	Total installed weight, lb, of the complete system excluding spare parts.
X_{10}	Major housings	Total number of cabinets or housings containing one or more electronic chassis. If physically separable from a major housing, the antenna is also counted as a housing.

All of the values for the dependent and independent variables, as measured for the eight completed projects, are summarized in Table 4.

Preliminary Calculations: To reduce the mass of data in Table 4, a first calculation was made on the data. This calculation was made with a view towards eliminating any of the variables which were not too useful due to (1) low predictive accuracy, (2) unavailability or resistance to measurement at the "proposal stage" of a project, or (3) being intuitively deemed of low predictive merit.

These first calculations were performed on punched-card equipment and the following parameters were obtained for each pair of dependent and independent variables:

1. LEAST SQUARES ESTIMATING EQUATION. This is the least squares fit between distinct points on

Table 4—Completed Project Data

Variable	Item	Project A	B	C	D	E	F	G	H
Dependent Variables									
Y_{20}	System engrg. (hr)	300	1000	280	880	260	620	2500	680
Y_{21}	Element engrg. (hr)	2000	2580	3140	2800	1200	1320	12,260	1480
Y_{22}	Element test (hr)	900	1680	2240	680	420	960	4340	780
Y_{23}	System test (hr)	1080	1220	1260	1860	1060	1380	8420	840
Y_{24}	Total engrg. (hr)	4280	6480	6920	6220	2940	4600	27,520	3780
Y_{25}	Drafting (hr)	3320	2890	6800	5560	11,700	5800	16,030	3120
Y_{26}	Total engrg. & drafting (hr)	7600	9370	13,720	11,780	19,640	10,400	43,550	6900
Y_{27}	Technician staff (hr)	1250	1500	2270	1000	870	2550	9640	900
Y_{28}	Technical publication (hr)	1625	1700	4500	5160	5420	2810	9100	2000
Y_{29}	Model shop (hr)	880	3250	10,170	387[illegible]	5330	2890	31,500	4620
Y_{30}	Model shop mat'l (dollars)	6280	2250	26,230	11,400	8050	8680	16,300	2800
Y_{31}	Engrg. mat'l (dollars)	1150	6500	10,480	3900	2820	5430	57,400	4210
Y_{32}	Total project cost (dollars)	64,700	92,950	158,200	136,250	149,400	139,750	584,700	90,300
Y_{33}	Total manhours	11,335	15,820	30,660	21,810	31,260	18,650	93,790	14,420
Independent Variables									
X_1	Functions	4	4	6	6	7	7	11	6
X_2	Circuits	11	13	10	13	11	10	21	10
X_3	Assemblies	3	4	13	8	10	7	14	5
X_4	Circuits & assemblies	14	17	23	21	21	17	35	15
X_5	Tubes	36	83	87	29	40	31	132	18
X_6	Components	115	202	235	116	180	91	503	69
X_7	Chassis area (sq in.)	860	1470	1630	1187	1260	1134	14,600	396
X_8	Antenna weight (lb)	50	40	2990	670	3	135	600	110
X_9	Equipment weight (lb)	108	238	3550	2023	1630	344	2100	380
X_{10}	Major housings	3	6	2	3	3	6	7	2

Table 5—Calculated Correlation Coefficients for Different Combinations of Dependent and Independent Variables

Dependent Variables	Independent Variables X_1	X_4	X_2	X_3	X_5	X_6	X_7	X_8	X_{10}	X_9
Y_{20}	0.7868	0.7967	**0.9626**	0.4485	0.7110	**0.8138**	**0.921**[illegible]	0.1156	0.7524	0.1165
Y_{21}	**.8029**	**.9003**	**.9419**	.6746	**.8392**	**.9414**	**.9864**	.1462	.6041	.3676
Y_{22}	.7521	**.8596**	**.8560**	.6891	**.9465**	**.9439**	**.9087**	.3507	.6000	.4218
Y_{23}	**.8436**	**.8917**	**.9381**	.6622	.7677	**.9091**	**.9943**	.0345	.6588	.3019
Y_{24}	**.8268**	**.8992**	**.9472**	.6662	**.8368**	**.9369**	**.9905**	.1205	.6536	.3364
Y_{25}	**.9861**	**.9225**	.7820	**.8923**	.6107	.8181	**.8060**	.1037	.4052	.5156
Y_{26}	**.9562**	**.9660**	**.9215**	**.8222**	.7701	**.9394**	**.9546**	.0872	.5629	.4403
Y_{27}	**.8428**	**.8699**	**.8813**	.6837	**.8116**	**.9129**	**.9820**	.1121	.7051	.2965
Y_{28}	**.9916**	**.9884**	**.8456**	**.9469**	.6237	**.8203**	**.8170**	.2533	.3274	.6683
Y_{29}	**.8550**	**.9314**	**.8607**	**.8224**	**.8333**	**.9485**	**.9699**	.2435	.5103	.4821
Y_{30}	.5551	.6508	**.9859**	**.8984**	.5273	.5023	.3529	**.9087**	.1246	**.9179**
Y_{31}	**.8057**	**.8860**	**.8842**	.7106	**.8334**	**.9394**	**.9932**	.1294	.6401	.3475
Y_{32}	**.9312**	**.9464**	**.9205**	.7856	.7819	**.9296**	**.9866**	.1165	.6174	.4031
Y_{33}	**.8219**	**.9376**	**.8255**	.6212	.6454	.7655	**.9495**	.1097	.3462	.3140
Total	11.7578	12.4465	12.5530	10.3239	10.5386	12.1211	12.6127	2.8316	7.5081	6.9295

Correlations having value of 0.8000 or more are shown in bold face.

a scatter chart of an independent (X) and dependent (Y) variable. When expressed in the form of an equation of the type, $Y = a + bX$, this relationship becomes known as an "estimating equation."

2. STANDARD ERROR OF ESTIMATE. This term reveals a general measure of the scatter or distribution of variable values around the mean "plot" indicated by the estimating equation. It yields an estimate of the range above and below the mean line, within which 68.27 per cent of a very large number of estimates may be expected to fall if the scatter is normal. This is sometimes referred to as the one-sigma limit and is directly analogous to one standard deviation in normal curve analysis.
3. CORRELATION COEFFICIENT (ψ). This term states the degree of explained relationship between a pair of variables. This is stated in concise numerical terms and gives an indication of the choice of variables being analyzed.

All of these calculations are indicated for one pair of variables, X_4 and Y_{32}, in Fig. 2.

Complete data for all the pertinent statistical parameters were similarly evaluated on an IBM 602-A calculating punch using standard statistical techniques.* It was through the use of this punched card equipment that the many mathematical formulas could be economically solved. By means of this equipment, values for the foregoing parameters 1, 2 and 3 for 140 combinations of X and Y variables were computed in about the same total time and effort as one person with a desk calculator would require to manually compute and check just one combination. A summary of all the correlation coefficients thus calculated is given in Table 5.

*Editor's Note: A detailed description of how these parameters were evaluated is available on request from: MACHINE DESIGN, Editorial Dept., Penton Bldg., Cleveland 13, O.

Adjustment for Sample Size: All correlation computations in the case discussed here are based on a sample size of eight. The correlation in a sample tends to be higher than in the population from which the samples are drawn. This is especially true when the sample size is small. Estimating the correlation in the population may therefore be thought of as making allowance for the size of the sample. The best estimate of correlation in the population is obtained from:

$$\bar{\psi} = \frac{\psi(n-1)-(m-1)}{(n-m)} \qquad (1)$$

where n = sample size, m = number of constants in the estimating equation (two in the case of simple linear correlation), ψ = correlation coefficient of the sample, and $\bar{\psi}$ = corrected coefficient

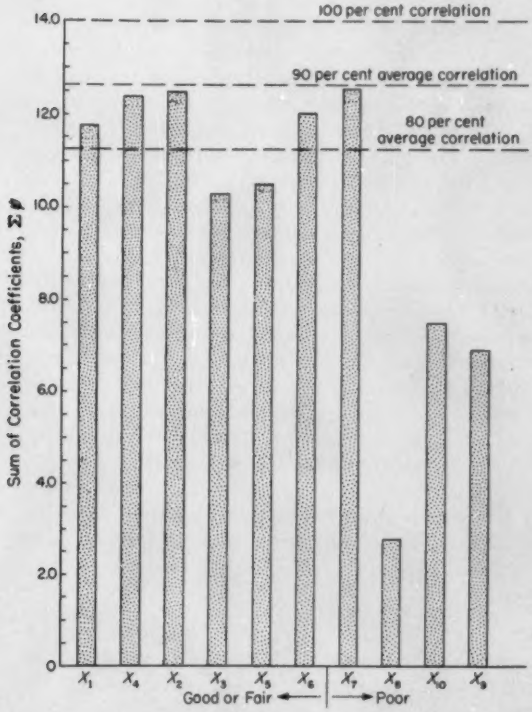


Fig. 3—Analysis of correlation between each independent X variable and the sums of correlation coefficients for 14 dependent Y variables. Bar plots are based on data given in Table 5. Location of X variables, from left to right, indicates ranking in order of merit based on a subjective rating of plausibility, measurable accuracy and availability.

Table 6—Rating of Independent Variables

Variable	Characteristic	Merit
X_1	Functions	Good
X_4	Circuits and assemblies	Good
X_2	Circuits	Good
X_3	Assemblies	Good
X_5	Tubes	Fair
X_6	Components	Fair
X_7	Chassis area	Fair to Poor
X_8	Antenna weight	Fair to Poor
X_{10}	Major housings	Poor
X_9	Equipment weight	Poor

Table 7—Rating of Dependent Variables

Variable	Item	Rating
Y_{32}	Total project cost	Very Good
Y_{33}	Total manhours	Very Good
Y_{24}	Engrg. hours	Good
Y_{25}	Drafting hours	Good
Y_{27}	Technician staff hours	Good
Y_{28}	Technical publications hours	Good
Y_{29}	Model shop hours	Good
Y_{30}	Model shop material	Good
Y_{31}	Engineering material	Good
Y_{20}	System engrg. hours	Fair
Y_{21}	Element engrg. hours	Fair
Y_{22}	Element test hours	Fair
Y_{23}	System test hours	Fair
Y_{26}	Engrg. and drafting hours	Poor

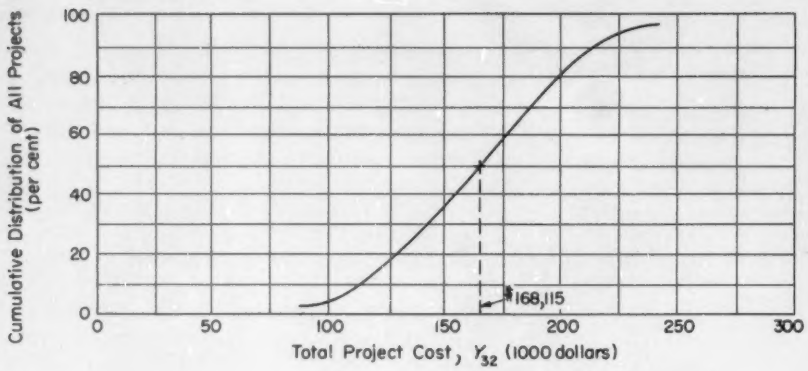


Fig. 4 — Cumulative frequency distribution curve for analysis of variation of dependent variable Y_{32} (total project cost) when the independent variable X_4 (circuits plus assemblies) is fixed. Curve plot is based on probable distribution of actual values from mean value (Equation 2) for $X_4 = 20$.

value. For this particular example, $n = 8$ and $m = 2$.

Reduction of Independent Variables: The independent variables X_1 through X_{10} are ranked in order of their merit. This ranking was based on a subjective evaluation of the variables, considering their measurable accuracy, availability at the proposal stage, and plausibility. This rating is given in Table 6.

For each of the X variables, a general estimate of their usefulness was further established by summing the values of the corresponding correlation coefficients for all 14 Y variables, as shown at the bottom of Table 5. This summation gives a further means of eliminating low correlation X variables. On the basis of the presentations in Fig. 3 and Table 6, only the variables X_1, X_2, X_4, and X_6 would normally be selected for further analysis. However, since X_2 is encompassed by X_4, it was felt that X_4 was a more practical value for estimating and X_2 was omitted.

Table 8—Basic Estimating Relationships

Variables	Relationship
X_1, Y_{32}	Functions vs. total project cost
X_1, Y_{33}	Functions vs. total manhours
X_4, Y_{32}	Circuits and assemblies vs. total project cost
X_4, Y_{33}	Circuits and assemblies vs. total manhours
X_6, Y_{32}	Components vs. total project cost
X_6, Y_{33}	Components vs. total manhours

Table 9—Factor Ratings*

Factor	Project A	B	C	D	E	F	G	H
A. Design Requirements	90	85	25	35	40	90	70	50
B. Personnel Qualifications	70	70	50	60	70	30	50	40
C. Co-ordination	40	70	60	70	80	30	40	70
D. Turnover	30	50	50	70	70	50	90	70
E. Scheduling	20	30	60	10	70	15	15	15
F. Product Potential	25	25	70	70	50	60	90	90

*Based on factor rating sheet, Fig. 1. All values in per cent.

Reduction of Dependent Variables: The Y variables were also ranked in order of their merit. The criteria guiding this evaluation were the usefulness of the Y values in preparing the proposal documents and in setting internal budgets by organizational units. This ranking of the dependent variables appears in Table 7.

On the basis of this analysis, only dependent variables Y_{32} and Y_{33} were retained for further analysis.

Estimating Relationships and Limitations: At this point, the basic estimating equations which can be used are all combinations of X_1, X_4 and X_6 with Y_{32} and Y_{33}, Table 8.

Each of these estimating equations is useful due to the high correlation coefficient and relatively low standard deviation. For example, refer back to the correlation of X_4 versus Y_{32}, Fig. 2. However, specific projects do deviate enough from the mean line to render the project cost as obtained from the equation to be significantly different from the actual total incurred cost.

From familiarity with the actual circumstances surrounding particular projects, a list might be drafted of what will be termed "factors" which influenced performance on one project more than another. In this case, a list of factors was so prepared and will be statistically analyzed.

Evaluation of an Estimating Equation: From examination of the plot of Fig. 2, an estimating equation was obtained:

$$Y_{32} = 23{,}777\, X_4 - 307{,}425 \qquad (2)$$

where Y_{32} is the total project cost and X_4 is the summation of all circuits plus assemblies in the project. It was also determined that the standard error of estimate, when the value of X_4 was 20 (an average sized project), was ±$39,600. The mean value of all projects this size will be $168,115. In graphical terms, it may be represented as a "cumulative frequency distribution" Fig. 4.

This distribution function points up one of the principal features of statistics. The estimating

equation, when given a certain X input, produces a Y value. But also, by specifying the standard deviation, it can be indicated just how far from the mean value any particular value may range, given a large number of trials. For example, consider an infinite number of samples with $X_4 = 20$. The average value of Y_{32} will be \$168,115. In 68.27 per cent of the instances, the actual value will fall between \$128,515 and \$207,715. In only 0.27 per cent of the instances, will the value fall below \$49,315 or above \$286,915 (the 3-sigma limits, $Y_{32} = 168{,}115 \pm 3 \times 39{,}600$), Fig. 4.

The fact that there is still a range on both sides of the mean in which a specific estimate may fall does not detract from the value of the estimating equation. Since the exact mean of a group of projects has been accurately determined, the operation of the department over a period of time will find some high and some low projects which tend to cancel each other out. Further, the upper 1 or 2-sigma limits can be used as criteria for quoting a development on a fixed price basis and the lower 1-sigma limit for quoting on a cost-plus-fixed fee basis. Then again, the use of factors may explain more of the extreme deviations from the mean.

Risk in Using Equations: The whole basis for estimating is on the assumption that the eight samples obtained are part of an underlying distribution or population. It is desirable to determine the accuracy of this assumption and evaluate the magnitude of the "calculated risk" in using any estimating equation. A test for the validity of this statement is the t test. Details on its application are given in *Reliability of Correlation Coefficient*. Based on this computation, if Equation 2 is used to determine total dollars cost, Y_{32}, from a measure of X_4, relying on the statistical relationship between the variables Y_{32} and X_4, the probability that the relationship between the variables actually is governed by statistical correlation is 99.9 per cent (level of significance by t test is 0.001). That is, if this estimating equation were used to describe the relationship in 1000 companies with similar sets of data on X_4 and Y_{32}, it is probable that 999

Table 10—Coefficients of Correlation Between Estimating Variables and Factors*

Factor	Variables X_1/Y_{32}	X_4/Y_{32}	X_6/Y_{32}	X_1/Y_{33}	X_4/Y_{33}	X_6/Y_{33}
A. Design Requirements	0.1348	0.1378	0.2475	0.2700	0.2700	0.3878
B. Personnel Qualifications	−.0239	.4784	**.7289**	−.2762	.2553	**.6928**
C. Co-ordination	.1502	.2803	.2036	.0334	.1437	.1422
D. Turnover	−.5521	−**.7859**	−**.6116**	−.4594	−**.7637**	−**.6235**
E. Scheduling	.1233	.0364	.3453	−.3058	−.1865	.2327
F. Product Potential	−.2929	−**.6882**	−**.8082**	−.1788	−**.6326**	−**.8562**

*Values of coefficients of correlation are based on the values of the six pairs of variables and six factors obtained for Projects *A* to *H*.
All points with a coefficient of correlation of 0.600 or more are shown boldface.
A minus sign indicates the existence of an inverse relationship; that is, as the value of the factor increases, the value for the pair of variables decreases.

Reliability of Correlation Coefficient

To find whether or not one observed correlation coefficient is significantly greater than zero, the t test is useful, regardless of the size of the sample. The method consists in computing the value of t from:

$$t = \frac{\bar{\psi}\,(n-m)^{1/2}}{(1-\bar{\psi}^2)^{1/2}}$$

where n is the same size, m is the number of constants in the estimating equation and $\bar{\psi}$ is the computed correlation coefficient of the population, Equation 1.

For the specific example discussed in this article, Fig. 2, $n = 8$, $m = 2$ and $\bar{\psi} = 0.9375$. From the foregoing equation then, $t = 6.89$.

For $t = 6.89$ and a value of 6 for the "degrees of freedom" (this value corresponds to the sample size minus the number of constants, $m - n$), by consulting a "t table" an indication is obtained of the number of times out of 1000 that a sample, drawn from a population with zero correlation, will give the results of a correlation coefficient as high as that actually obtained. For this example, the table indicates a "level of significance" of 0.001 for the given values of t and degrees of freedom.

Since the chance of a zero correlation population existing is very low, the correlation is assumed to be significant. A further conclusion is that a correlation coefficient with a value of 0.9375 could hardly have been due to chance, if based on a sample drawn from a population having zero correlation.

sets of data actually are correlated and that one set of data has no correlation. This corresponds to a calculated risk in using the estimating equation of 0.1 per cent. A statistician calls this event Type II error; that is, the probability, when a correlation is assumed to exist between variables, that in reality no such correlation does exist.

Rating the Factors: A list of what was considered to be the cause for specific projects not following the mean line of the estimating equation was compiled. The extremes of each factor were rated as 0 per cent and 100 per cent and an attempt was made to describe all conditions between the extremes by a *numerical* value as shown on the factor rating sheet, Fig. 1. After completion of each project, the technical personnel associated with the project were asked to fill out a factor rating sheet and "rate" or "score" each factor. A summary of factor rating results compiled for the case under discussion is given in Table 9.

Before the coefficients for each factor are determined and integrated into the estimating equations, those factors which are of limited value will be eliminated. This will be done by computing correlation coefficients between each factor and each estimating equation. Instead of using the estimating equation itself ($Y = a + bX$) a ratio of variables, Y/X, will be used for calculating simplicity. Either the equation itself or the foregoing ratio would serve as a basis for indicating whether X and Y have any correlation to the factors. Each of the pairs of variables used in the estimating equations will be treated as a new variable and evaluated, in turn, against each of the six factors. If any factor shows a consistently low correlation, it will be dropped from further analyses.

From an inspection of the results shown in Table 10, all relations containing variable X_1 bear low correlation to all the factors presented. This can be taken to mean that the factors selected do not have a consistent relationship to the ratio involving "functions," X_1, or that the quantitative value of X_1 is so small as to cause any relations based on it to depend too greatly on its value. That is, if the estimator miscalculated the value of X_1 by one unit, his estimate would very likely be unusable.

Final Evaluation: From an analysis of Table 10, some conclusions on the operation of the organization can be drawn.

The three most influential factors affecting the values derived from an *X-Y* estimating equation are, in order of their importance:

1. Potential of product.
2. Personnel turnover.
3. Personnel qualifications.

These factors are usually responsible, in a qualitative manner, for increased expenditures over what would be considered "average" when using an estimating equation to determine such values. A logical follow-through is for management to evaluate product potentials carefully, to exercise more control over the qualifications of technical personnel, and to attempt to reduce turnover through an appraisal of its basic causes, remedying same where possible.

Further Calculations: While not discussed in this article, to state the conclusions quantitatively a multiple correlation must be undertaken, progressively adding the factors *F*, *D* and *B*, in that order, and examining the value of the correlation coefficient with each addition.

It would be expected in general for the coefficient of correlation to become progressively larger as the number of variables are increased. Indicated in Fig. 5 is simply a graphic portrayal of how a coefficient of multiple correlation ($R_{1.2345}$) can be calculated using the basic relationships between pairs of variables or factors. Also, as each factor is added, a new term is obtained to be added to the estimating equation which would indicate, say, the probable total costs for a given project when it is anticipated that a generally low level of qualified personnel will be utilized on the project. However, for a sample of eight projects, the statistical reliability of these more complex estimating equations deteriorates rapidly. Unless more samples (completed projects) can be obtained, it is not advisable from a practical standpoint to develop these more complex equations from the sample points available.

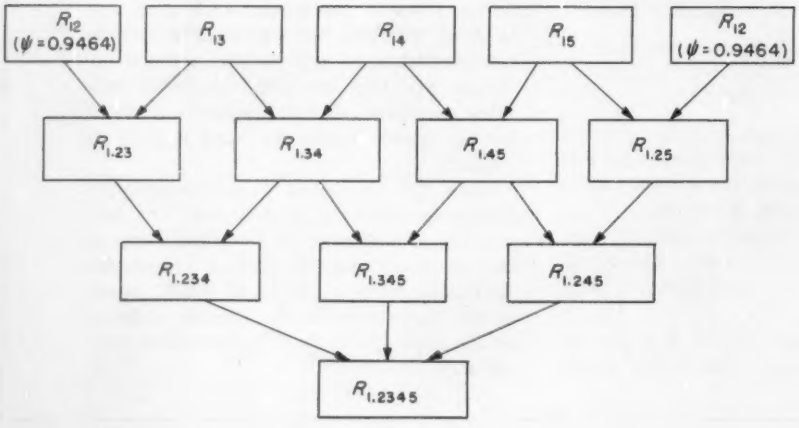
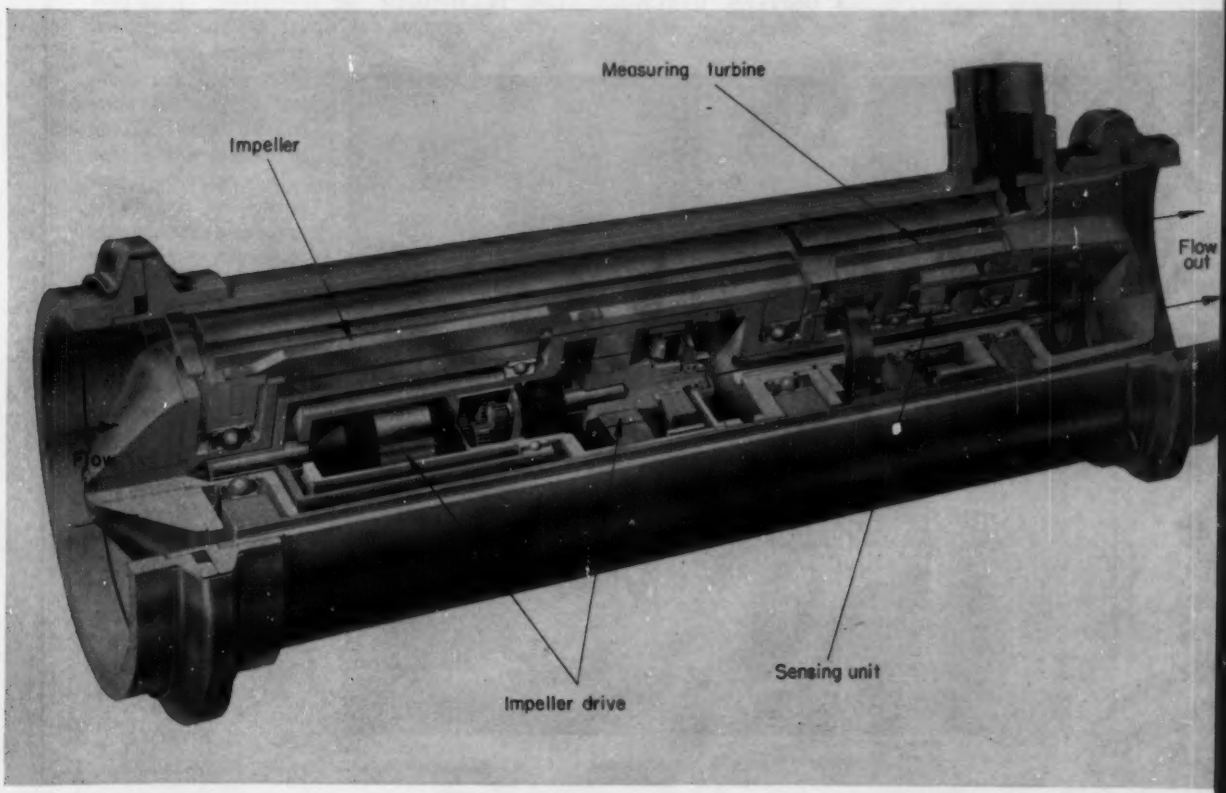


Fig. 5—Flow of calculation required to determine a multiple correlation coefficient. The multiple correlation coefficient is designated $R_{1.2345}$ while subscripts identify individual items as follows: 1 = independent variable X_4; 2 = dependent variable Y_{32}; 3 = factor *F*; 4 = factor *D*; and 5 = factor *B*.

scanning the field for *Ideas*

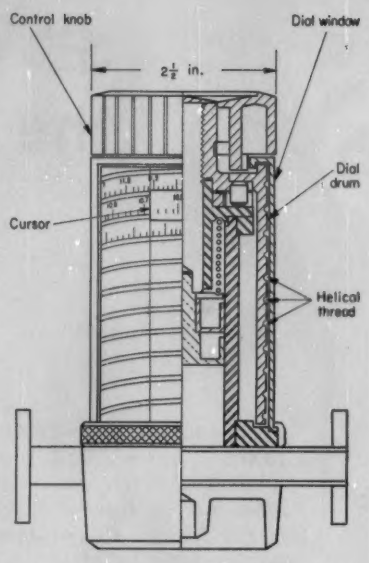
ACCURATE MEASUREMENT OF FLUID FLOW is accomplished by a novel method of continuous weighing. In a mass flowmeter developed by Inertial Instruments Inc. primarily for use in jet aircraft fuel systems, precise metering of liquids, gases or liquid-gas combinations is obtained by measuring fluid momentum.

As a liquid or gas passes through the flowmeter, it is given a precise angular velocity by an impeller, which is driven by a governor-controlled motor. A measuring turbine at the outlet end of the meter reduces this angular velocity to zero. Since the original angular acceleration is constant and known, the torque necessary to remove the angular velocity of the fluid is a measure of the mass accelerated and, in turn, mass flow. Torque developed in the measuring turbine activates a calibrated spring made of Ni-Span C. The deflection of this spring is converted by an output transducer into an electrical signal which can be transmitted to a dial indicator, a digital counter, and/or a totalizer.

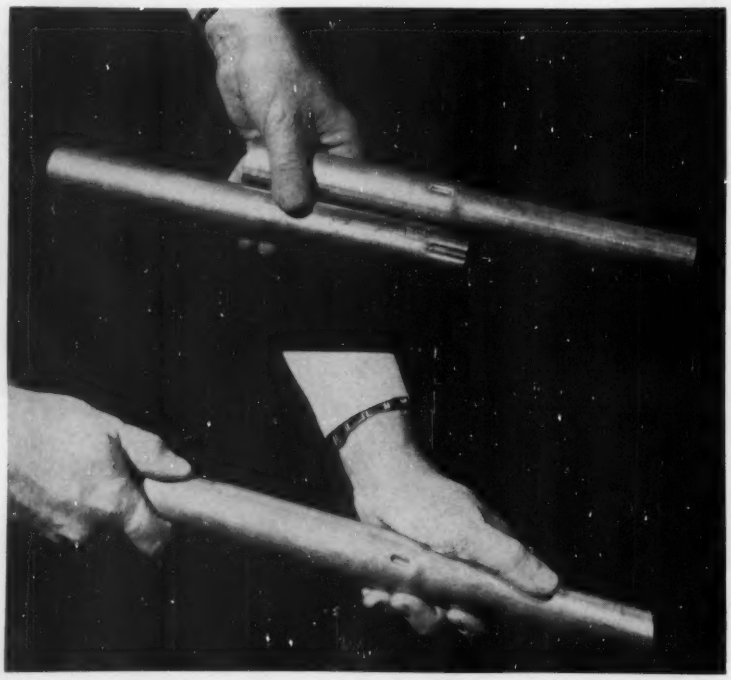


HELICAL DIAL DESIGN offers high accuracy and readability in a Hewlett-Packard direct-reading waveguide frequency meter. The scale markings are imprinted along one edge of a helical thread on the dial drum. The length of the scale is more than 32 times the diameter of dial drum.

In design, the back of the cursor fits into two adjacent thread grooves on the dial drum. The front of the cursor fits into a slot on the inside of the dial window. Turning the dial drum by means of the control knob forces the cursor to move in a plane parallel to the axis of meter.



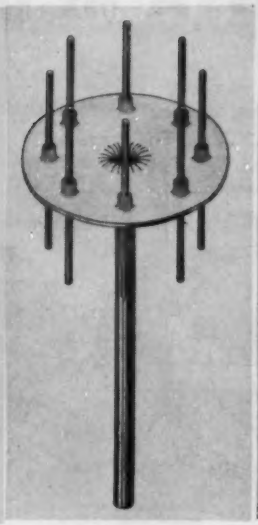
POSITIVE, QUICK-LOCKING TECHNIQUE for fabricating metal tubing offers cost and time-saving advantages. A novel method has been developed by Armco Steel Corp. for locking lengths of zinc-coated steel tubing in TV antenna masts.

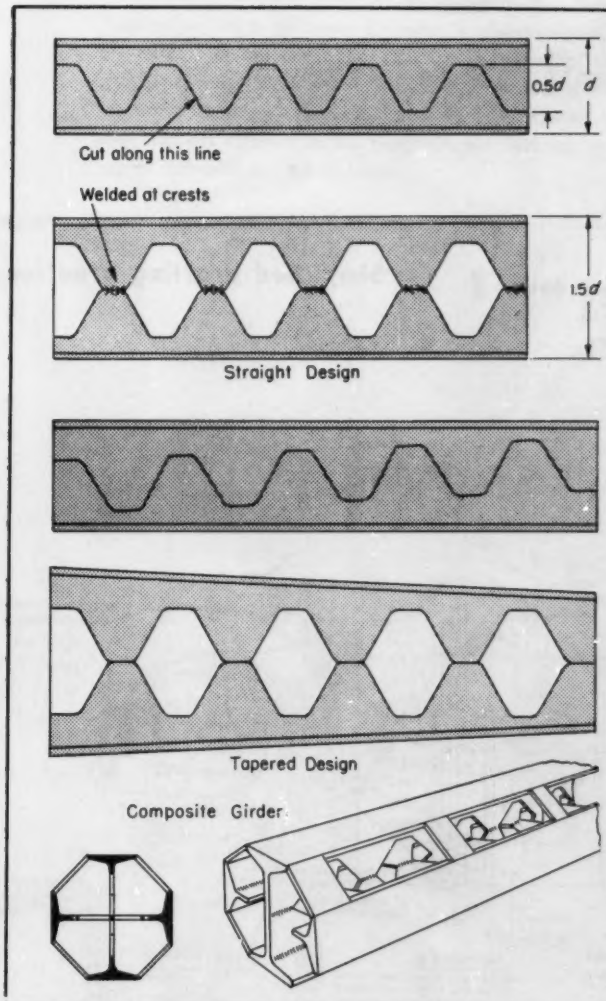


In construction, one section of a tube is expanded sufficiently to permit another section of unexpanded diameter to telescope inside it. A dimple is pressed into the expanded section and a mating groove into the end of the tube that slips inside it. When the two sections are slipped together, the locking dimple and groove fit together so tightly that the completed joint will not turn.

IDEAS

WAFER STEM CONSTRUCTION used in Sylvania electronic tubes offers greater ruggedness and life expectancy. The circular arrangement of lead-in wires molded in a glass wafer permits using large-diameter conductors which provide for fast heat conduction away from tube elements. Also, the wafer shape allows wide spacing between leads reducing the voltage gradient. As a result the stem electrolysis and internal arcing are minimized, and the method of construction increases resistance to vibration.





CASTELLATED CONSTRUCTION more than doubles rigidity and load capacity of long beams without increasing weight. Modulus and flexural inertia of an I-beam section are increased by about 56 and 135 per cent, respectively. Corresponding reduction of shear strength is appreciable only in the case of short spans.

The construction is produced by first flame cutting the web of an ordinary I-beam along the line indicated. Then one of the halves is turned end for end and welded to the other half at the crests. Although the resulting beam may be 50 per cent greater in depth, it has effectively the same weight as the original I-beam and has no appreciable loss of strength. Also the holes in the castellated beam may be used for passage of piping, cables, etc. Tapered beams can be made by inclining the general direction of web cuting. Composite girder forms can be fabricated by interlocking cross-shaped sections of castellated beams and plate-batten toe connections.

The patented design, which was reported by H. E. Handyside, Northumberland, England, is known as the Boyd system and is now the property of the Appleby-Frodingham Branch of the United Steel Companies.

Do you have a novel design idea for our other readers? You can receive ten dollars or more for each idea accepted for exclusive publication in this department. Send a short description plus drawings or photos to: "Scanning the Field for Ideas," MACHINE DESIGN, Penton Bldg., Cleveland 13, O.

The Rules of

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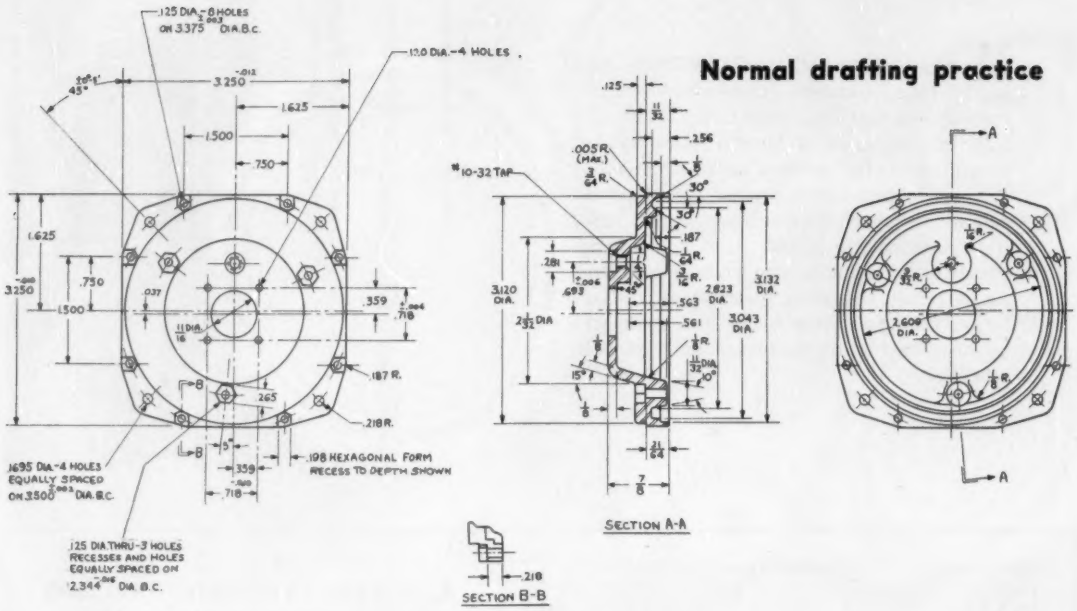


NOTES:

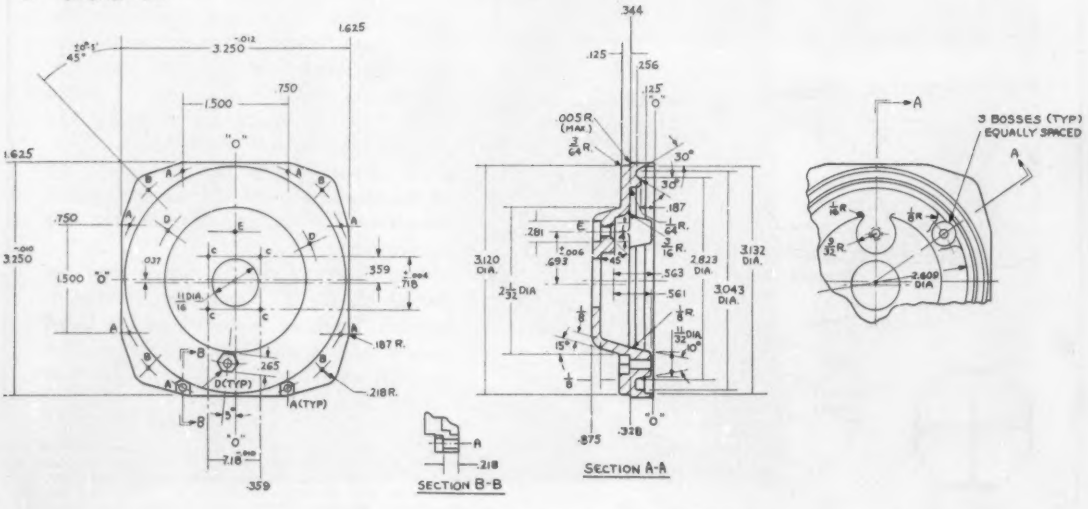
1. DIAMETERS MARKED (*) MUST BE CONCENTRIC WITHIN .003 F.I.R.
2. ALL RADII TO BE 1/32 UNLESS OTHERWISE SPECIFIED

Simplified drafting practice

HOLES	OPERATION
"A"	.125 DIA. - 8 HOLES - THRU. ON 3.375 ± .003 DIA. B. C.
"A"	.198 HEXAGONAL FORM RECESS TO DEPTH SHOWN IN SECT. B-B.
"B"	.1695 DIA. - 4 HOLES - THRU. EQUALLY SPACED ON 3.500 ± .022 DIA. B.C. *
"C"	.120 DIA. - 4 HOLES - THRU
"D"	.125 DIA. THRU. - 3 HOLES RECESS & HOLES EQUALLY SPACED ON 2.344 .016 DIA. B.C. *
"E"	#10-32 TAP - THRU

NOTES:

1. DIAMETERS MARKED (*) MUST BE CONCENTRIC WITHIN .003 F.I.R.
2. ALL RADII TO BE 1/32 UNLESS OTHERWISE SPECIFIED



Simplified Drafting in Action

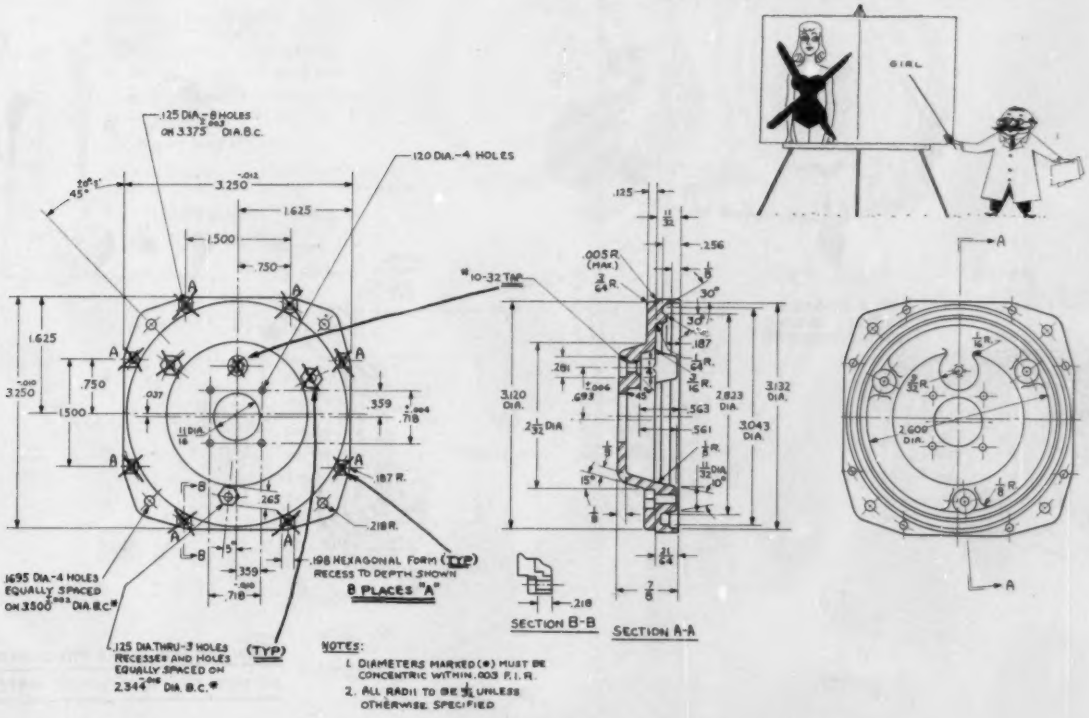
By Jay H. Bergen, *Standards Administrator*
General Engineering Laboratories
American Machine and Foundry Co.
Greenwich, Conn.

Here are 11 basic principles that have proved to be time-saving and practical at AMF:

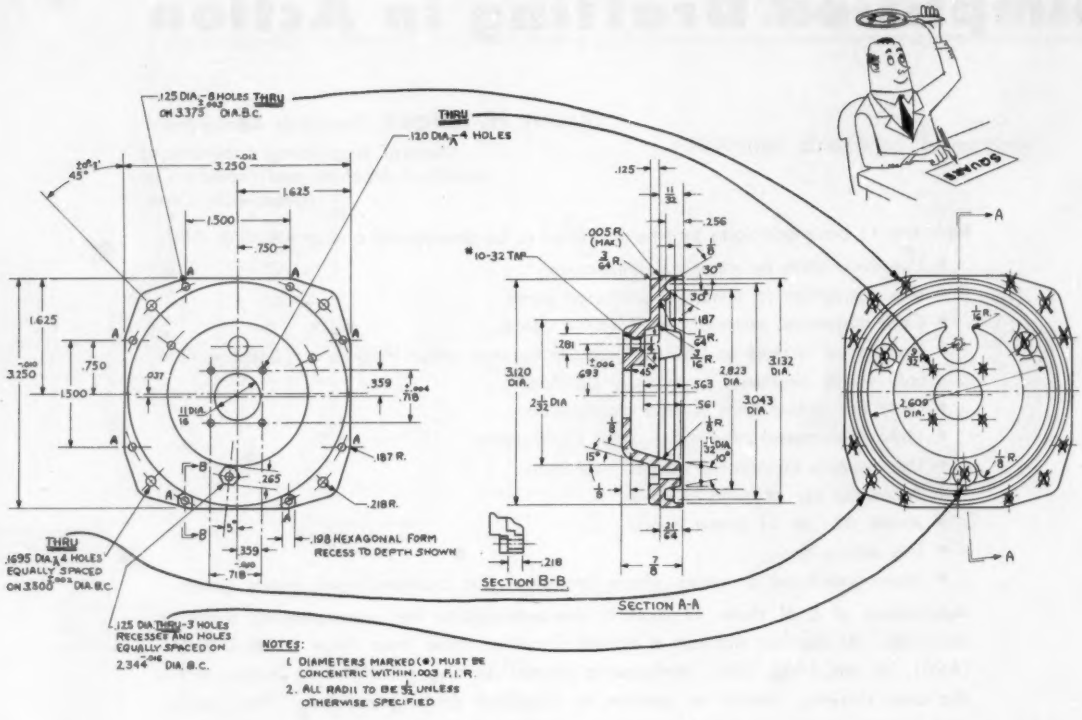
- Use description to eliminate delineation.
- Use description to eliminate projected views.
- Omit elaborate, pictorial, or repetitive detail.
- Use keyed legend to indicate nuts, bolts and other hardware. Show outline only where necessary to indicate position.
- Only use dotted lines to add clarification.
- Only use cross-sectioning to add clarification.
- Use symbols to indicate various hole sizes.
- Avoid the use of hand lettering.
- Avoid the use of arrow heads.
- Use datum lines.
- Make free-hand drawings where possible. Use cross-sectioned board cover.

Application of 8 of these 11 rules is demonstrated in the accompanying series of drawings. At top left appears a typical drawing, taken from Page 8, MIL-0-5028A (ASG), 28 Jan. 1954, which conforms to normal drafting practice. At bottom left is the same drawing altered to conform to simplified drafting practice. The step-by-step changes involved in this transition are outlined in the remaining drawings appearing on this and successive pages.

1 Use description to eliminate delineation.

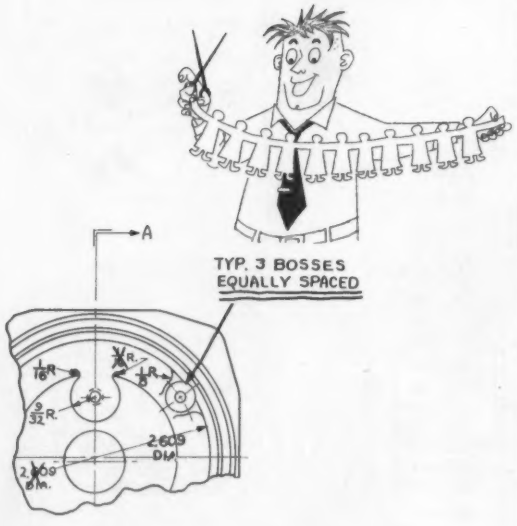

GIRL
.125 DIA.-8 HOLES ON 3.375 DIA. B.C.
.120 DIA.-4 HOLES
3.250
1.625
1.500
.750
#10-32 TAP
.198 HEXAGONAL FORM (TYP) RECESS TO DEPTH SHOWN 8 PLACES "A"
.1695 DIA.-4 HOLES EQUALLY SPACED ON 3.500 DIA. B.C.*
.125 DIA. THRU-3 HOLES RECESSES AND HOLES EQUALLY SPACED ON 2.344 DIA. B.C.*
(TYP)
SECTION B-B
SECTION A-A
NOTES:
1. DIAMETERS MARKED (•) MUST BE CONCENTRIC WITHIN .003 F.I.R.
2. ALL RADII TO BE 1/16 UNLESS OTHERWISE SPECIFIED

2 Use description to eliminate projected views.

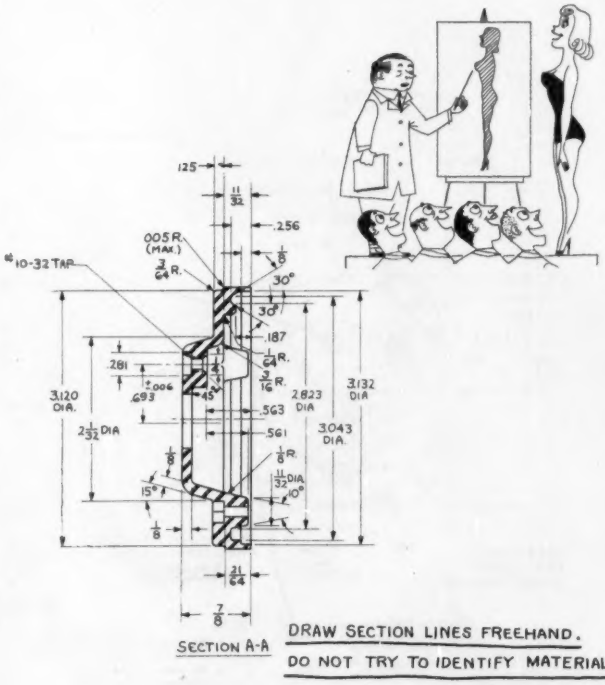


NOTES:
1. DIAMETERS MARKED (⌀) MUST BE CONCENTRIC WITHIN .003 F.I.R.
2. ALL RADII TO BE 1/32 UNLESS OTHERWISE SPECIFIED

3 Omit elaborate, pictorial, or repetitive detail.



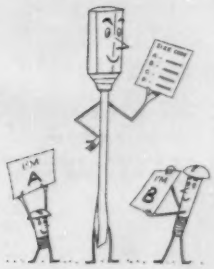
4 Only use cross-sectioning to add clarification.

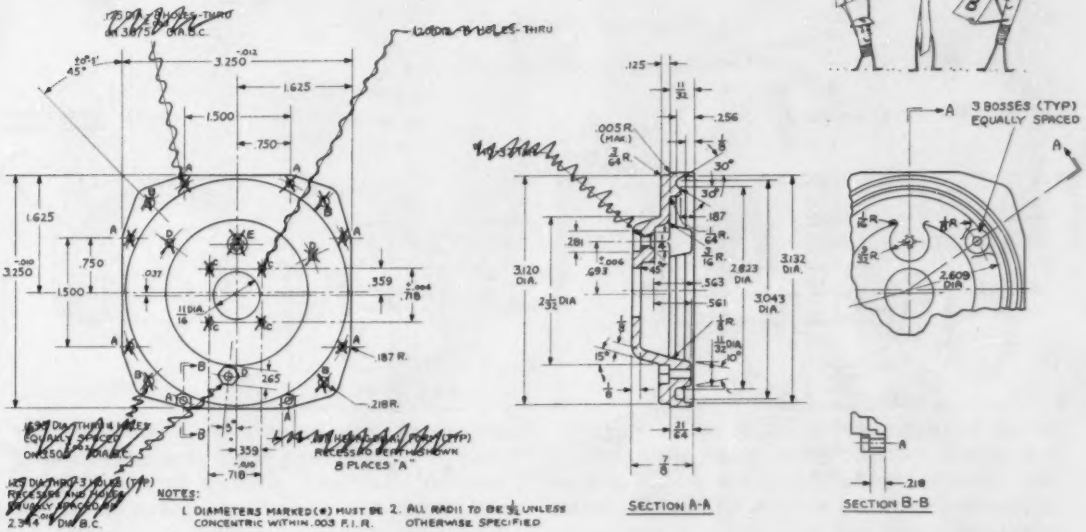


DRAW SECTION LINES FREEHAND. DO NOT TRY TO IDENTIFY MATERIAL.

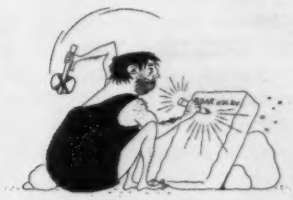
5 Use symbols to indicate various hole sizes.

HOLES	OPERATION
"A"	.125 DIA- 8 HOLES-THRU. ON 3.375 $^{\pm.003}$ DIA. B.C.
"A"	.198 HEXAGONAL FORM RECESS TO DEPTH SHOWN IN SECT. B-B
"B"	.1695 DIA.- 4 HOLES- THRU. EQUALLY SPACED ON 3.500 $^{\pm.002}$ DIA B.C.
"C"	.120 DIA - 4 HOLES-THRU.
"D"	.125 DIA. THRU.- 3 HOLES RECESS ¢ HOLES EQUALLY SPACED ON 2.344 $^{-.016}$ DIA. B.C.
"E"	* 10-32 TAP-THRU.

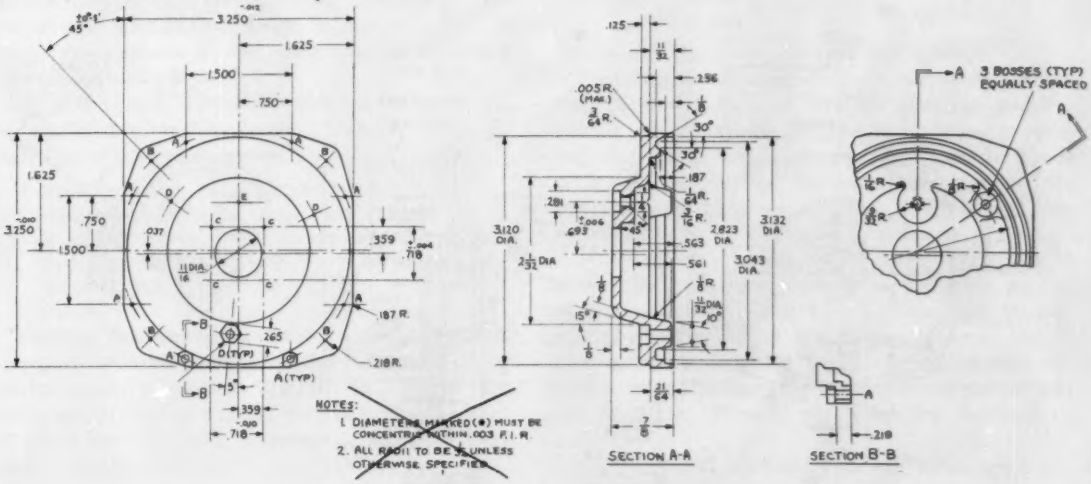



3 BOSSES (TYP) EQUALLY SPACED
SECTION A-A
SECTION B-B
NOTES:
1. DIAMETERS MARKED (*) MUST BE CONCENTRIC WITHIN .003 F.I.R.
2. ALL RADII TO BE ⅛ UNLESS OTHERWISE SPECIFIED

6 Avoid the use of hand lettering.



HOLES	OPERATION
"A"	.125 DIA- 8 HOLES- THRU. ON 3.375 $^{\pm.003}$ DIA. B.C.
"A"	.198 HEXAGONAL FORM RECESS TO DEPTH SHOWN IN SECT. B-B
"B"	.1695 DIA.- 4 HOLES- THRU- EQUALLY SPACED ON 3.500 $^{\pm.002}$ DIA. B.C. *
"C"	.120 DIA. - 4 HOLES- THRU.
"D"	.125 DIA. THRU- 3 HOLES RECESS ¢ HOLES EQUALLY SPACED ON 2.344 $^{-.016}$ DIA. B.C. *
"E"	* 10-32 TAP- THRU.

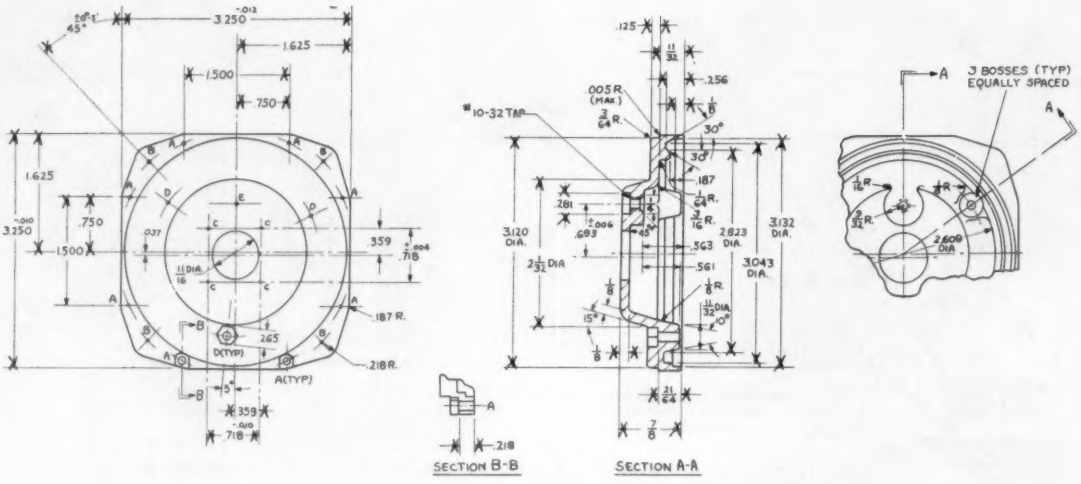

3 BOSSES (TYP) EQUALLY SPACED
SECTION A-A
SECTION B-B
NOTES:
1. DIAMETERS MARKED (*) MUST BE CONCENTRIC WITHIN .003 F.I.R.
2. ALL RADII TO BE ⅛ UNLESS OTHERWISE SPECIFIED

7 Avoid the use of arrow heads.

HOLES	OPERATION
"A"	.125 DIA. - 8 HOLES - THRU. ON 3.375 ± .003 DIA. B. C.
"A"	.198 HEXAGONAL FORM RECESS TO DEPTH SHOWN IN SECT. B-B.
"B"	.1695 DIA. - 4 HOLES - THRU. EQUALLY SPACED ON 3.500 ± .022 DIA. B.C. *
"C"	.120 DIA. - 4 HOLES - THRU
"D"	.125 DIA. THRU. - 3 HOLES RECESS & HOLES EQUALLY SPACED ON 2.344-.016 DIA. B.C. *
"E"	#10-32 TAP - THRU

NOTES:

1. DIAMETERS MARKED (*) MUST BE CONCENTRIC WITHIN .003 F.I.R.
2. ALL RADII TO BE 1/32 UNLESS OTHERWISE SPECIFIED



8 Use datum lines.

HOLES	OPERATION
"A"	.125 DIA. - 8 HOLES - THRU. ON 3.375 ± .003 DIA. B. C.
"A"	.198 HEXAGONAL FORM RECESS TO DEPTH SHOWN IN SECT. B-B.
"B"	.1695 DIA. - 4 HOLES - THRU. EQUALLY SPACED ON 3.500 ± .022 DIA. B.C.
"C"	.120 DIA. - 4 HOLES - THRU
"D"	.125 DIA. THRU. - 3 HOLES RECESS & HOLES EQUALLY SPACED ON 2.344-.016 DIA. B.C.
"E"	#10-32 TAP - THRU

NOTES:

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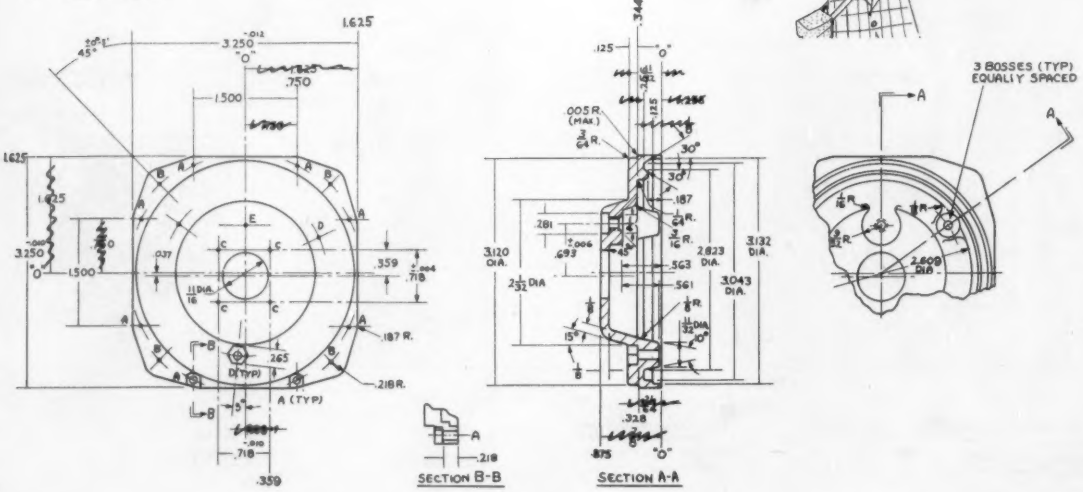


Hydraulic Servos—1

Practical methods for analyzing typical systems

By J. M. Nightingale
Manchester, England

SERVOMECHANISMS, although self-contained units in themselves, are generally part of more complex overall systems. Their main function is to provide power amplification with high positional accuracy. In short, they provide the muscle so that a weak signal of the kind associated with measuring devices can harness sufficient power to overcome the operating forces associated with bulky machinery. This also entails matching the response and stability characteristics of the servo with those of the overall system.

Choice of working medium, that is, hydraulic, pneumatic or electric power, is often quite arbitrary. However, factors which influence the ultimate choice are so diverse that each case must be treated on its own merits. Generalized arguments such as *hydraulics versus pneumatics* can only be made if idealizing constraints are imposed on each system, and the results obtained from such arguments are at best a guide to supplement the experience and know-how of a design team. In many cases choice of operating medium is largely solved by availability.

In this article, hydraulic servomechanisms will be analyzed in rather detailed fashion. Main advantages of hydraulic servos are:

1. Power to weight ratio is high.
2. Construction can be simple and reliable.
3. Working medium, i.e. hydraulic fluid, is stiff so that controlled variable is not easily influenced by external loads.

System Requirements: Some common applications of hydraulic servos in the control field are engine speed regulation, machine tool tracer controls, and powering aircraft control surfaces. Each of these will be briefly discussed to illustrate common system requirements.

Purpose of an engine speed regulating system is to keep the engine speed constant despite fluctuations in the fuel supply and the external load torque. Reasonable success has been achieved by constraining the fuel flow and hence the engine torque directly by a governor of the rotating flyball kind. An improvement is achieved by inserting a servo between the governor and the fuel pump. With the servo, the governor has only to supply a small fraction of the power needed to operate the fuel pumps. As a consequence the governor can be smaller and a more precise measuring device. In a particularly interesting system, Fig. 1, the governor displacement directly controls a hydraulic pressure which is used to operate a valve-cylinder relay. Here the hydraulic relay is an integrating device; that is, its output displacement, y, is

$$y(t) = K_r \int_0^t x(t)dt \qquad (1)$$

where x is the governor arm displacement.

From the block diagram for the overall system, Fig. 1*b*, it will be seen that the governor and hydraulic relay combine to give isochronous governing, at least in theory. In practice it will be found necessary to modify the characteristics of the hydraulic unit to insure stability. Use of stabilizing networks is to be discussed in a future article.

Function of a machine tool tracer system is to insure that the workpiece is an accurate replica of the template. Cross-slide of the tool is constrained by the output of a hydraulic servo, Fig. 2. The device is sensitive to the error between the stylus, which is integral with the cross-slide, and the template. Thus a purely virtual feedback is achieved.

Accuracy and sensitivity in the servo are para-

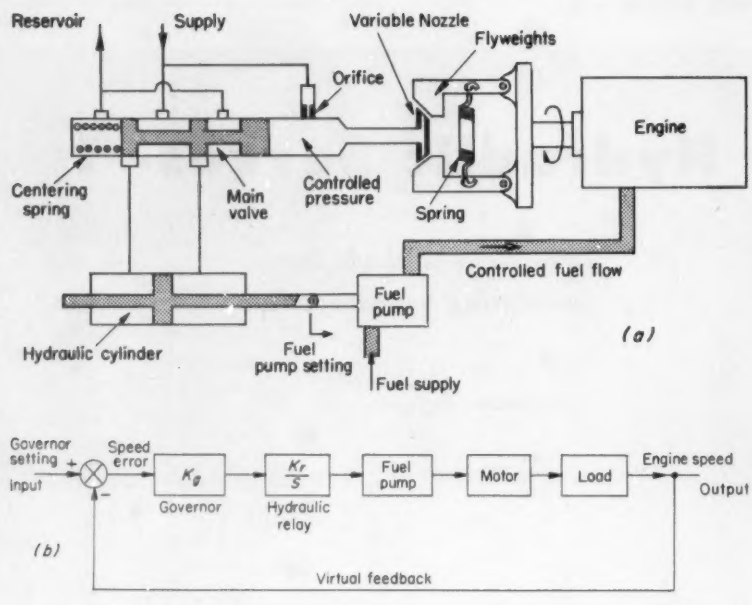


Fig. 1—Control of engine speed is a common servomechanism application. In this system, *a*, a governor of the flyball type is used to control a hydraulic relay consisting of a valve and cylinder. Cylinder output adjusts fuel flow to maintain nearly constant engine speed. Since the governor or input device is directly coupled to the engine, feedback is said to be virtual, *b*.

mount since both static and following errors must be within the tolerances of the workpiece. Output loads vary due to the uneven depth of cut and hence the servo must be very stiff as viewed from the output end. In this connection it is advantageous to use high supply pressures.

The field of aircraft powered surface controls is becoming more and more important as the speed and size of aircraft increase. The whole system is very complex and includes the aerodynamic properties of the aircraft and the characteristics of the pilot or autopilot as well as those of the control system. Analysis of the complete problem is very complicated because, for example, human response is difficult to express analytically, and also because the aircraft has several degrees of freedom each with its own set of controls. One problem connected with the latter is the interaction between a control and the other degrees of freedom. Indeed so many parameters are variable that the only really practical way to investigate the complete problem is by an analog model.

From overall design considerations emerge the requirements for the control units themselves. Although, basically, accurate position control with considerable power amplification is the main requirement, it is becoming obvious that by providing special response characteristics some contribution can be made to improve the overall controlled-flight behavior of the aircraft. To sum up, the flying control is emerging from the stage of being merely a proportional amplifier into a frequency-sensitive device with characteristics tailored to suit the complete system.

In a typical powered flying control system, Fig. 3, the input force has only to overcome the valve friction force and can be of the order of a few pounds or even ounces. Output force seen by the cylinder piston can, on the other hand, be several tons. High supply pressures of the order of 4000 psi are favored to reduce the weight and bulk of components. System pressures may go higher yet. Accuracy demands may not be too severe, but sensitivity requirements may be extreme for mechanical systems. Accurate response may be required up to 50 cps. In terms of pump demands this will normally be about 50 cu in. per sec.

As previously stated the controls are part of a complex aeroelastic structure. At high speeds it is possible for continuous oscillations of the airframe, called flutter, to be set up and maintained by energy drawn from the slipstream. To avoid increasing the likelihood of flutter the control should, in general, be very stiff against output load changes when viewed from the output end. In some cases the pilot is provided with an input stick force which depends on the output load, a proportional relationship holding in very simple cases. Thus, not only the response characteristics of the servo but its stiffness viewed from either end must be considered. These properties can be likened to the transmission and impedance parameters of electrical four-terminal networks. This analogy will be shown more fully later on.

Often the response of a hydraulic servo must be critically damped; none of its modes can be oscillatory. This condition may be difficult to achieve because of the inertia of the load (control surface) together with compliances in the system, such as compressibility of the hydraulic fluid. To isolate the inertia from the control system the servomotor sometimes drives through an irreversible screw. This may introduce problems of its

own due to backlash and friction and certainly reduces the efficiency of the unit.

If valve-cylinder combinations are used, Fig. 3, then trouble can be caused by relative movements between the output and input stations due to high output loading. This introduces unwanted error signals into the loop and can make for instability.

This brief discussion of the requirements of some common servo systems is included to set the stage for the following analysis of typical hydraulic servos. The servos to be analyzed might well be used to perform the tasks just outlined. Methods to be used have been discussed in previous articles.[1–5] Components used in building up the systems to be analyzed were considered in other previous articles.[6–9]

Hydraulic Servo Analysis: Possibly the best known hydraulic servo unit is the valve-cylinder relay, Fig. 4. Such a device was briefly considered previously but a number of assumptions were made in order to roughly determine its design parameters. A transfer function was developed to describe its response characteristics, but this is of only limited value. If the unit is used as a preamplifier and its output load is small, such that that maximum differential cylinder pressure is less than about 1/10 P_s, the earlier analysis is quite reasonable. But when the valve-cylinder servo is used as a main power drive, analysis is complicated by dynamic output loading. The general effect is to reduce stability of the unit.

The valve-cylinder relay, Fig. 4, is a self-contained closed-loop system. Feedback is purely virtual due to the valve casing and cylinder being integral and floating. In other systems mechanical feedback is achieved by using a lever differential to compare the input and output displacements.

When the valve is displaced from center as shown in Fig. 4, the flow equations are:

$$\left.\begin{aligned} Q_1 &= f(X)\sqrt{P_s - P_1} \\ Q_2 &= f(X)\sqrt{P_2} \end{aligned}\right\} \qquad (2)$$

Under steady conditions the flow through each

[1]References are tabulated at end of article.

Nomenclature

A	= Effective cylinder piston area
f	= Damping constant
$f(X)$	= Function describing exposed valve port area variation with X
Θ_i	= Input displacement
Θ_o	= Output displacement
K	= Slope gain constant for small perturbations of system
K_g	= Gain constant of governor
K_r	= Gain constant of hydraulic relay
k	= Spring constant
m	= Inertia constant
N	= Bulk modulus of fluid
P_c	= Differential cylinder pressure
P_{co}	= Steady-state value of P_c
P_s	= Supply pressure
P_1, P_2	= Cylinder pressures
p_c	= Small perturbation in P_c
Q	= Cylinder flow
Q_d	= Disturbed flow
Q_o	= Steady-state value of Q
Q_1, Q_2	= Flows into and from cylinder through valve ports
q	= Small perturbation in Q
s	= Laplace operator
V	= Effective volume of fluid under compression
X	= Relative valve displacement
X_o	= Steady-state value of X
x	= Increment in X
$Y_c(s)$	= Overall transfer function
$Y_o(s)$	= Loop transfer function
θ_o, θ_i	= Incremental changes in output and input
λ_c	= Stiffness of fluid column in cylinder
λ_v	= Valve stiffness

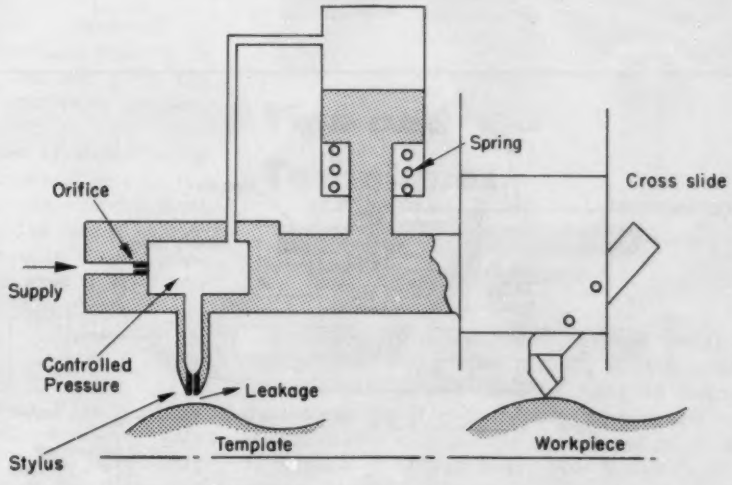


Fig. 2—In a position-control servo used as a machine-tool tracer control, feedback is provided by the gap between the stylus and the template. Increased leakage rate resulting from increasing gap between the stylus and the template results in action to reduce the gap and thus maintain a true contour.

valve port will be substantially equal, or $Q_1 = Q_2 = Q$. Then from Equation 2

$$P_s = P_1 + P_2 \tag{3}$$

Also

$$P_c = P_1 - P_2 \tag{4}$$

By solving for P_1 and P_2 and substituting in Equation 2

$$Q = f(X)\sqrt{\frac{P_s - P_c}{2}} \tag{5}$$

The function $f(X)$ shows how the exposed area of each port varies with displacement X from the dead center position of the valve stem. In order to use linear analysis the relation between Q and X must be proportional, but in practice this is hardly likely either by purpose or accident. If then some general nonlinear function $f(X)$ is assumed, the problem passes into the realms of nonlinear mechanics. The techniques already established for methodical analysis of servos are, therefore, not applicable. However, linear theory provides such a clear picture of system behavior and is so convenient for investigating the effect of changing parameters that it is worthwhile trying to employ it in the present case though it is at best only an approximation.

Various techniques exist for linearizing nonlinear equations. The simplest of these, known as the *small perturbation* method, will be adopted here. In effect the method consists of considering only small disturbances which are superposed on a steady-state motion, in which the variables are considered to change so slowly they may be treated as constants. Although only an artifice this method is found to give useful results in servo system analysis. The closeness between theory and practice is influenced by the fact that proportional feedback tends to reduce nonlinear distortion and also because higher harmonics introduced by nonlinearity are severely attenuated or cut-off above the bandwidth of the servo.

A word of caution must be given here since both these mitigating influences will not hold for large disturbances. Large disturbances can only be investigated by nonlinear mechanics and here are found certain kinds of phenomena which cannot be described in terms of linear mechanics.

The small perturbation method is based upon an approximation obtained from a Taylor series expansion of a function. Thus if X_o is a constant

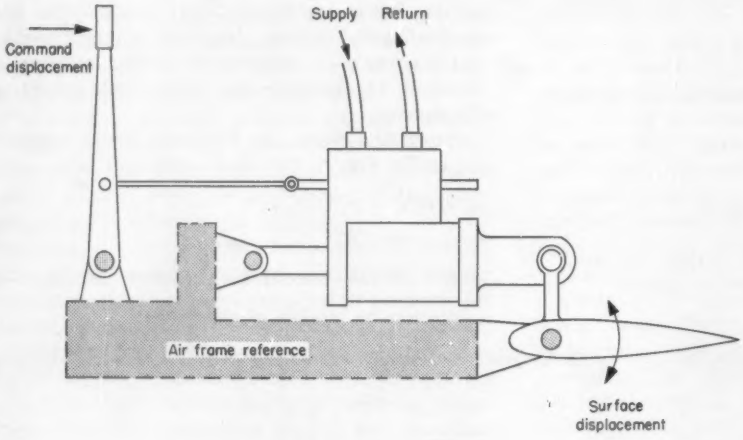


Fig. 3—A servomechanism such as this aircraft control surface operating system requires very little input force but must provide high output force. High output loads can cause distortion of the airframe upon which components are mounted to produce errors and instability.

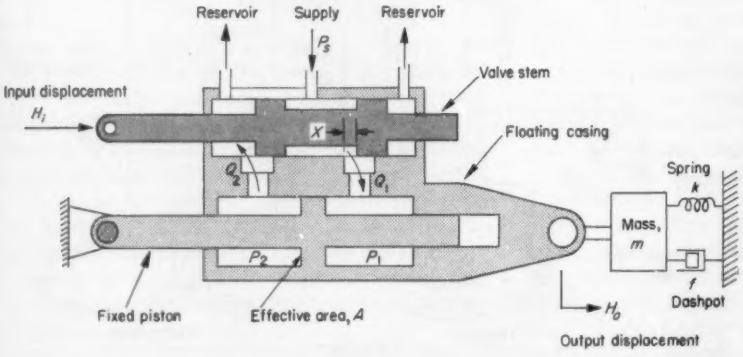


Fig. 4 — Section through a typical valve-cylinder relay. Feedback is virtual since cylinder and valve bodies are integral and floating. Relative valve travel gives direct measure of error. Analysis of this system is complicated by high output loading.

value of X, and x is a small increment in its neighborhood,

$$f(X_0 + x) \approx f(X_0) + xf'(X_0) \quad (6)$$

Higher terms of the expansion are neglected. The artifice adopted is to say that X_o is not really constant but varies so slowly with time that it may be regarded as being constant. Then the right-hand side of Equation 6 may be separated into two components, a steady-state quantity $f(X_o)$ which varies slowly, and a small perturbation term $xf'(X_o)$. In the small perturbation term $f'(X_o)$ is also considered constant and so the perturbation term is a linear function of the perturbation x. By considering only small perturbations in all the system variables a set of linear equations is obtained which describes the disturbed state of the system. It is then possible to investigate the stability of any steady-state motion of the system.

Since P_c in Equation 5 depends on the output load and cannot be regarded as constant, it is necessary to consider a small perturbation p_c about a steady quantity P_{co}. Disturbed flow from the valve is

$$Q_d = Q_0 + q = f(X_0)\sqrt{\frac{P_s - P_{co}}{2}} + x\left(\frac{\partial Q}{\partial X}\right) + p_c\left(\frac{\partial Q}{\partial P_c}\right) \quad (7)$$

where $\partial Q/\partial X$ and $\partial Q/\partial P_c$ are both evaluated for $X = X_o$ and $P_c = P_{co}$.

By separating out the perturbed components and introducing convenient parameters K and λ_v,

$$q = AK\left(x - \frac{Ap_c}{\lambda_v}\right) \quad (8)$$

where

$$K = \left(\frac{1}{A}\right)\left(\frac{\partial Q}{\partial X}\right)\Bigg]_{Q = Q_0}$$

and

$$\lambda v = -A\frac{\dfrac{\partial Q}{\partial X}}{\dfrac{\partial Q}{\partial P_c}} = A\left(\frac{dP_c}{dX}\right)\Bigg]_{Q = Q_0}$$

Factor K is the slope gain constant, while λ_v is called the *stiffness* of the valve and gives the gradient of cylinder effort against valve displacement for constant flow Q_o.

In addition to the component of flow tending to displace the cylinder, a component due to the compressibility of the fluid in the cylinder must be considered. This depends on the rate of change of P_1 and P_2. If the cylinder is in its mid-position, balanced flow exists for each side of the cylinder piston. Then for each side

$$Q = A\frac{d\theta_0}{dt} + \frac{V}{N}\frac{dP_c}{dt} \quad (9)$$

Here the effective volume of fluid, V, is ¼ of the total fluid in the cylinder. By considering only small increments in Q, H_o and P_c and introducing Laplace transforms,

$$q = As\left(\theta_0 + \frac{Ap_c}{\lambda_c}\right) \quad (10)$$

where $\lambda_c = A^2N/V$.

Finally, the load on the cylinder must be considered. In the general case the load includes inertia, damping and spring loads. Thus

$$AP_c = m\frac{d^2\theta_c}{dt^2} + f\frac{d\theta_0}{dt} + k\theta_0 \quad (11)$$

Considering perturbations and transforming

$$\Delta P_c = \xi(s)\,\theta_0 \quad (12)$$

where $\xi(s) = ms^2 + fs + k$.

Now by eliminating between Equations 8, 10 and 12 it is possible to obtain the loop transfer function,

$$Y_0(s) = \frac{\theta_0}{x}(s) = \frac{K}{s\left(1 + \dfrac{\xi}{\lambda_c}\right) + \dfrac{K\xi}{\lambda_v}} \quad (13)$$

since, in this case, valve displacement X is a direct measure of the error. The overall transfer function of the servo is, therefore,

$$Y_c(s) = \frac{\theta_0}{\theta_i}(s) = \frac{K}{s\left(1 + \dfrac{\xi}{\lambda_c}\right) + K\left(1 + \dfrac{\xi}{\lambda_v}\right)} \quad (14)$$

Equations 13 and 14 describe the disturbed behavior of the system about a pseudo steady-state condition. In the next part of this article these equations will be used to investigate the stability of the system and as a means of assessing its response.

References

This article is the ninth in a co-ordinated group by J. M. Nightingale on servo systems. The previous articles and the issues of MACHINE DESIGN in which they appeared are:

1. "Automatic Control Systems".....May 17, 1956
2. "Servo Mathematics".....June 28, 1956
3. "Evaluating Servo System Performance—Part 1".....July 26, 1956
4. "Evaluating Servo System Performance—Part 2".....Aug. 9, 1956
5. "Analyzing Servo Systems".....Nov. 1, 1956
6. "Hydraulic Servo Components—Part 1".....Nov. 29, 1956
7. "Hydraulic Servo Components—Part 2".....Dec. 13, 1956
8. "Hydraulic Servo Components—Part 3".....Dec. 27, 1956

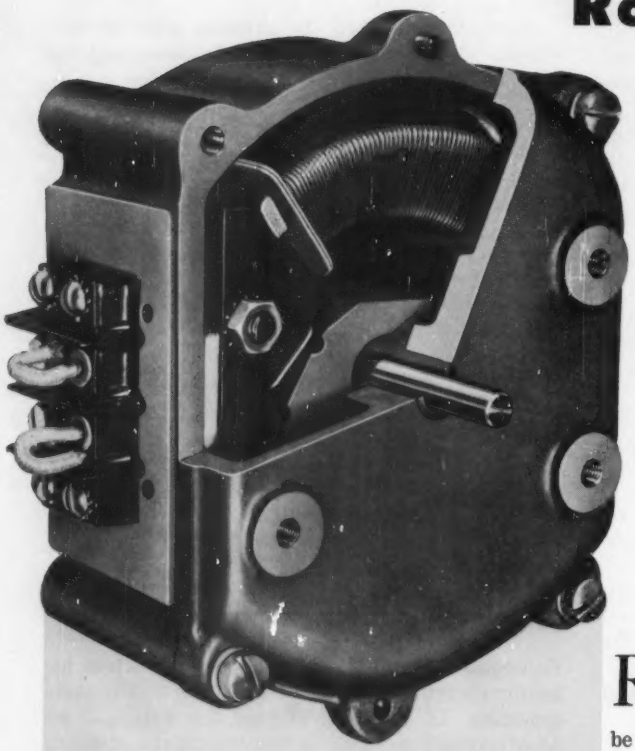
Tips and Techniques

Layout Pointer

A sharp-pointed instrument is very useful for making accurate, precise layouts. Such a pointer may be quickly improvised by using an ordinary mechanical pencil and a phonograph needle or a sewing needle with the eye end clipped off.—GENE J. KRYSKO, *design engineer, Dole Valve Co., Chicago.*

Selecting and applying

Rotary Solenoids



Rotary solenoids offer a number of design advantages in applications requiring torque through a limited angle. Application factors to be considered include total work loads along with solenoid size, cost, life and overall performance. Systematic procedures for determining loads plus basic hints in solenoid selection and application are presented in this article.

Fig. 1—Typical rotary solenoid design. Operated directly on ac power, this unit is composed of a coil system wound on a toroidal stator and a shaft-mounted rotor. This design rotates in a true plane without any axial shift of output shaft.

ROTARY solenoids are designed primarily to produce torque for a fixed angular movement. Their applied mechanical energy can be utilized to control valves, gates, ratchets, and similar mechanisms. A cutaway view of a typical ac type of rotary solenoid is shown in Fig. 1. The work produced at the shaft of this type of solenoid is similar to the force curve of a pull type linear solenoid.

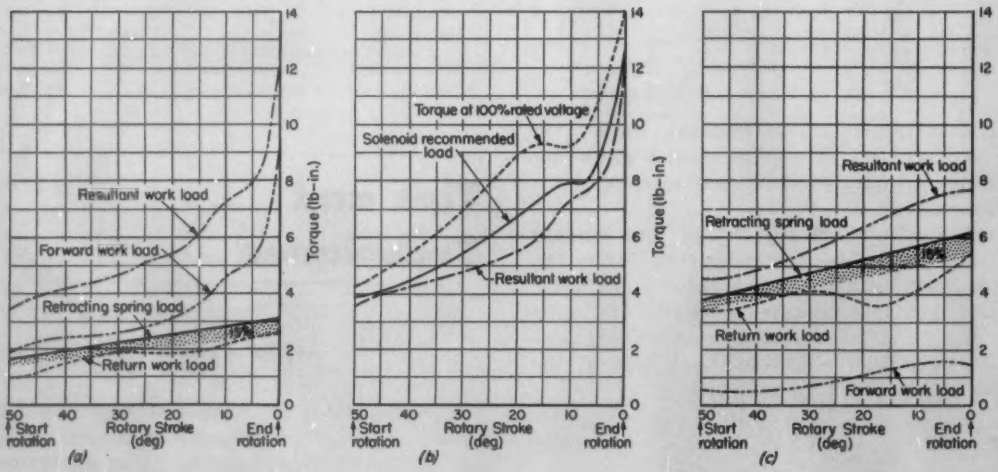


Fig. 2—Typical curves of torque versus rotary stroke for various load characteristics encountered in applying rotary solenoids.

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Rotary Solenoid Check List

1. **Electric Power**
   a. Voltage
      Nominal, maximum, minimum
   b. Frequency
      Nominal, maximum, minimum
2. **Duty Cycle**
   a. Continuous or intermittent
   b. Maximum *on* time
   c. Minimum *off* time
   d. Frequency of operation
3. **Direction of Rotation** (facing end of shaft)
   a. Right (clockwise)
   b. Left (counterclockwise)
4. **Rotary Stroke** (rotation angle required)
   a. Degrees
5. **Torque Requirements**
   a. At start of rotation
   b. At end of rotation
   c. Load characteristics
6. **Environmental Conditions**
   a. Ambient temperature
      Normal, maximum, minimum
   b. Vibration
   c. Shock
   d. Altitude
   e. Humidity
   f. Dust and dirt
   g. Salt spray
   h. Fungus
   i. Other

The first consideration in applying the rotary solenoid is the work to be done by the solenoid. This is associated with other factors affecting size, cost, life, and overall performance. The following discussion offers a guide to selection of ac rotary solenoids. In general, the same basic procedure could be employed in the selection of dc types.

Torque and Rotary Stroke: Because rotary motion is involved, the work stroke should be evaluated in degrees and treated in a manner similar to inches of stroke in push-pull type solenoids.

Frequently in the operation of solenoids, the *forward work load* and the *return work load* are different, Figs. 2*a* and *c*. Therefore, the load must be carefully determined at all intermediate stroke positions throughout the complete working cycle of the solenoid. Torque needed to overcome the work load during the forward stroke is supplied by the solenoid. During the return stroke the torque is generally supplied by a return or retracting spring; of course, this spring has to be loaded during the forward stroke. Thus, the solenoid must supply sufficient torque during its forward stroke to overcome both the forward work load and the *retracting spring load*. Therefore, forward and return work load must be tabulated and plotted in terms of torque versus stroke as ing Figs. 2*a* and *c*.

Of course, the retracting spring load developed by the retracting spring must exceed the return work load. In the solenoid design shown in Fig. 1, it is recommended that the spring should supply at least 15 per cent more torque than the return work load offers at any point during the return stroke. Plots of retracting spring loads that meet this design requirement are illustrated in Figs. 2*a* and *c*.

The *resultant work load* curve, Fig. 2*a*, is plotted by adding the retracting spring load to the forward work load. A rotary solenoid can then be selected that will furnish equal or more torque than the resultant work load. It is recommended by the manufacturer of the ac solenoid shown in Fig. 1 that required torque should be developed

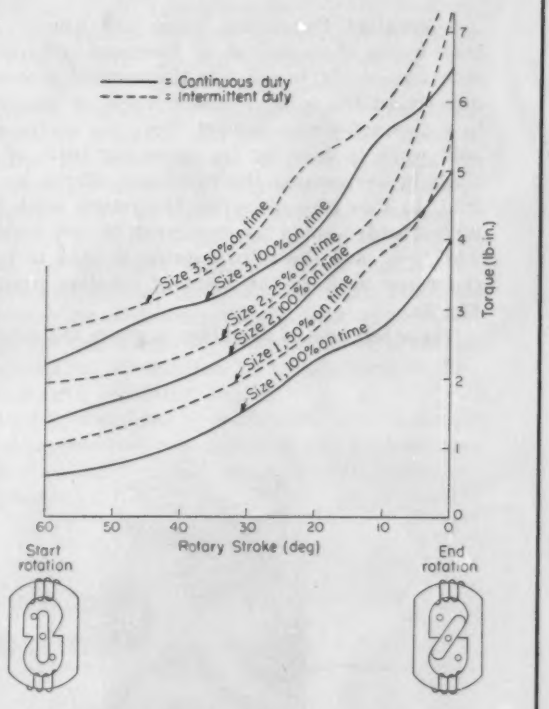


Fig. 3—Curves of torque versus rotary stroke for three sizes of rotary solenoids operating on continuous and intermittent duty.

Load Terminology for Rotary Solenoids

Return Work Load: The work required to return a load to its original position after the forward stroke is completed.

Forward Work Load: The work required to move a load through its intended stroke in a typical work cycle.

Retracting Spring Load: The work done by a spring in satisfying the return work load.

Resultant Work Load: The total work load offered to the solenoid. This is the sum of the *forward work load* and the *retracting spring load*. The solenoid must supply sufficient torque during its forward stroke to (1) move the work load and (2) load the retracting spring to restore the load to its original position when power to the solenoid is interrupted.

Recommended Load: The torque produced by a solenoid operated at a certain percentage of rated voltage with a recommended allowance for operating safety.

by the solenoid selected when it is operated at only 85 per cent of rated voltage. Plots of solenoid torque are shown in Fig. 2*b* that satisfy the recommended output torque requirement for the resultant work load curve determined in Fig. 2*a*.

Fig. 3 illustrates typical torque versus stroke characteristics obtained from rotary solenoids having different *on*-time ratings. Start of rotation corresponds to the position of the rotor when the solenoid coil is de-energized. When electrical energy is applied, the magnetic field set up by coil causes the rotor to turn until it comes to rest against the stator frame, which is the *end of rotation* position. Thus, the work stroke is completed and shaft torque produced is expressed in lb-in.

Application Functions: There are usually two basic types of operations or functions required of rotary solenoids. In one case the solenoid is coupled directly to the load, or the solenoid is connected to a forward-stroke ratchet. Here the useful solenoid work is done by the operating twist of the shaft in overcoming the resistance offered by the load. In this type of action the return work load is frequently small as compared to the forward work load and the return spring is used to bring the rotor back to the *start of rotation* position, Fig. 2*a*.

The other type of operation is where the solenoid is used primarily to load a spring, and the useful work is done by the spring as it unloads, Fig. 2*c*. Here the resultant work load is slightly greater than the retracting spring load. The forward work load is small and consists mainly of friction such as found in a ratchet device. This type of operation lends itself favorably to applications where the initial torque is high and decreases during the stroke. With minimum torque at the completion of a stroke, shock is virtually eliminated. Smaller solenoid sizes are frequently permitted when used for loading springs.

Duty Cycle: The size and cost of the solenoid selected for the job is effectively determined by the following factors:

1. Maximum number of operations per minute.
2. Maximum period of uninterrupted *on* time.
3. Minimum period of uninterrupted *off* time.
4. Maximum ambient temperature in which the solenoid is expected to operate.

In establishing these values, be as realistic as possible, taking care that item 3 is not too short and items 1, 2, and 4 are not overly high.

Review the solenoid selected, based on torque and rotary stroke requirements, with the torque curves of solenoids in the next smaller size to determine whether an intermittent-duty model meeting the calculated per cent *on* time will satisfy

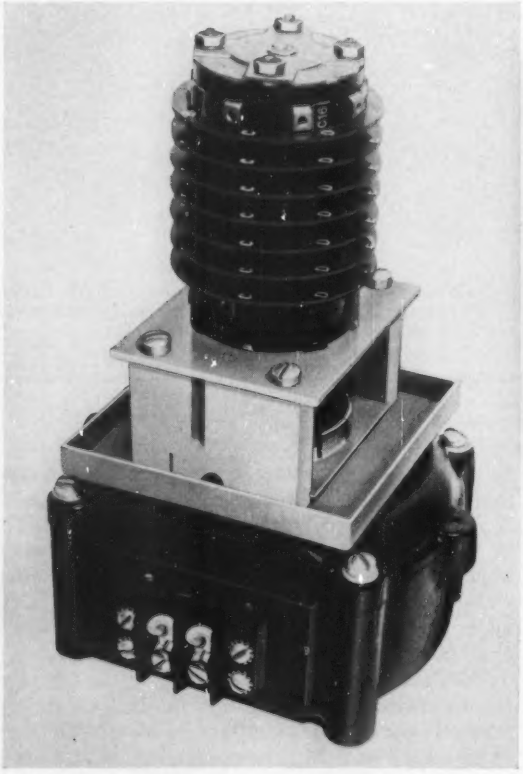


Fig. 4—Electro Switch Co. eight-position switch coupled to a Leetronics rotary solenoid providing complete power-stepping action.

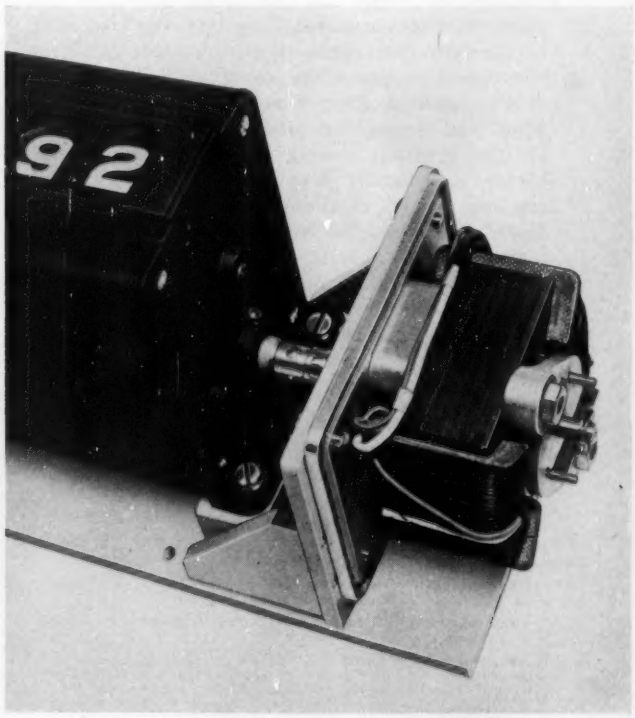


Fig. 5—Large Veeder Root counter powered by a rotary solenoid. Rapid forward and reverse rotating power was the design requirement satisfied.

the load under the specified duty conditions. Fig. 3 illustrates the variations of torque performance available in three solenoid sizes.

Application Hints: First of all, the designer should try to keep the stroke as short as possible. Since more torque is available at shorter strokes, it is frequently possible to use smaller-size solenoids, and that often means lower solenoid cost. Also, shorter strokes permit faster operations where speed is important.

It is a good idea to strive for balance. Essentially, the solenoid curve must be greater than the resultant work load curve, Fig. 2*b*, throughout the complete working cycle. Maximum mechanical life is achieved when the solenoid work equals the load work as the rotor completes its stroke. Any excess work produced by the solenoid is absorbed in the form of rotor "hammering" against the stator. From the viewpoint of efficiency, economy, and life, the solenoid selected should not be too large and overpower the application.

After a solenoid has been selected through the procedure given, redesign the retracting spring to take up the excess torque furnished by the solenoid.

Be sure to consider voltage conditions. The torque curves apply when 100 per cent rated voltage is applied to the solenoid. In general, torque varies as the square of applied voltage. At 85 per cent voltage, the solenoid torque is approximately 28 per cent lower than at rated voltage. In the selection of solenoid sizes, the effect of voltage variations on torque should be compared to the minimum expected voltage in the end application. Recommended load is the solenoid torque produced at 85 per cent rated voltage with a 20 per cent safety factor.

Solenoid protection is another important application consideration. Any ac-operated solenoid must be "pulled-in" within a very short time to prevent the inrush current from overheating the coil. Once energized, the rotor should complete its stroke to the pulled-in or end-of-rotation position without interruption. Where there is danger of rotor stalling because of overloading, mechanical interference, etc., it is recommended that solenoid protection against burn-out be provided by a time-lag fuse or other suitable protective device.

Typical Applications: Solenoids are used in automatically operated and controlled machines to perform key functions in programming and sequencing operations. A rotary solenoid used in connection with an eight-position rotary switch is shown in Fig. 4. In another application, rotary power for driving a large counter is supplied by a rotary solenoid, Fig. 5. Similar work functions in measuring and control-instrument applications utilize the advantages of rotary action of solenoids. Valve control is achieved in a metallurgical furnace control regulator, Fig. 6.

Other applications of these units include clutch operation, wire cutting, indexing, and related functions frequently called for in special machinery equipment.

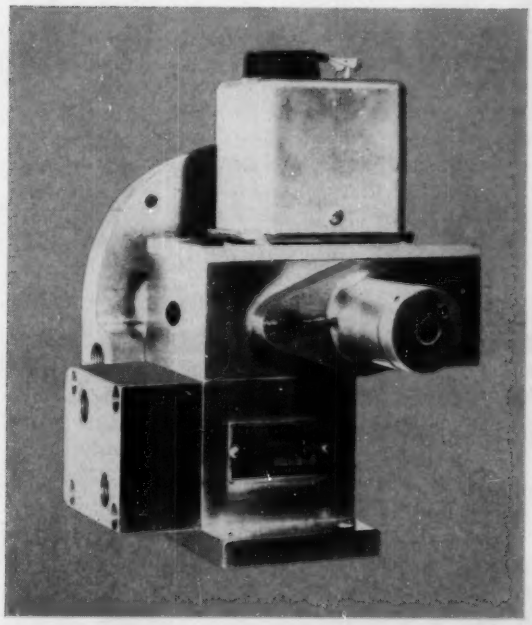
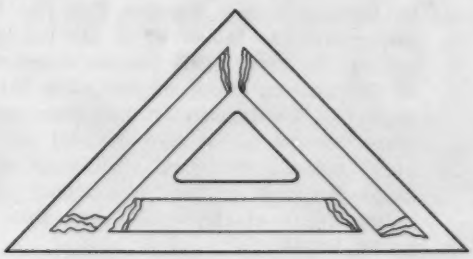


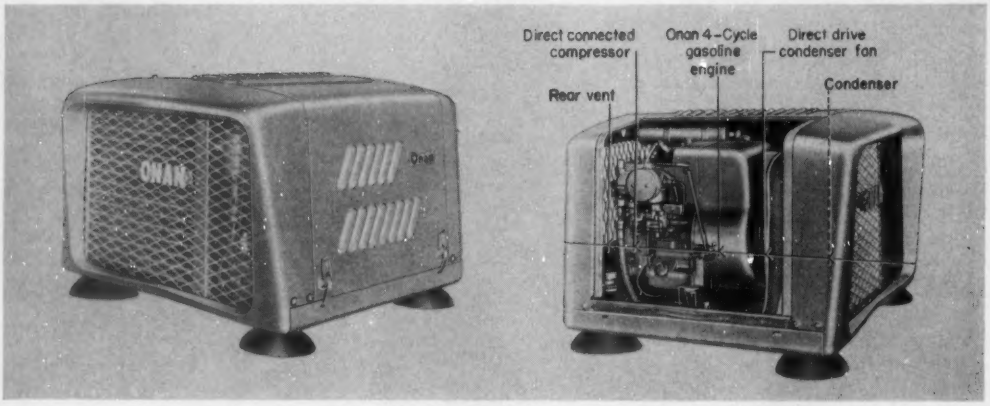
Fig. 6—Rotary-solenoid operated hydraulic relay system made by the Hague Regulator Corp. This solenoid must operate about once a minute around the clock.

Tips and Techniques

Preventing Ink Blots

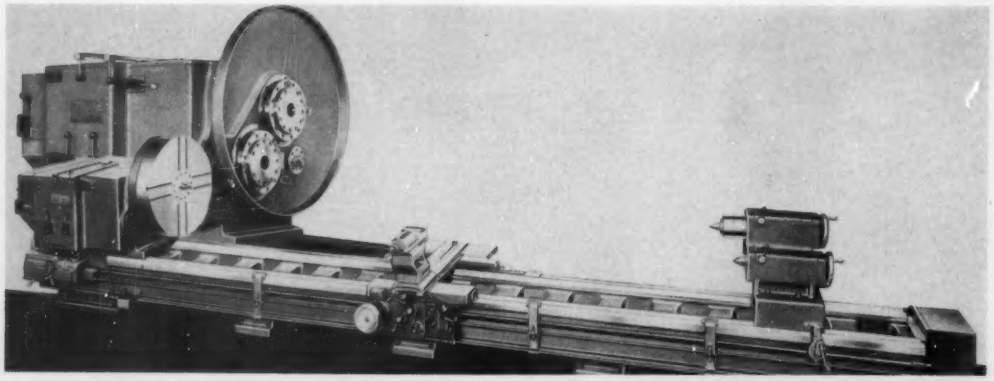
Ink can be prevented from running under the edge of a triangle or template by raising the edge serving as the pen guide above the surface of the paper. One of the simplest ways of achieving this is to apply a layer or two of drafting or masking tape to the instrument.—E. M. THORNTON, *drafting specialist, General Electric Co., Bloomington, Ill.*





Air Conditioner Designed for Quick Mounting

COMPLETELY self-contained, a new 1⅓-ton capacity air conditioning unit is designed for mounting on vehicle cabs with virtually no installation. Made by D. W. Onan and Sons Inc., the unit, called the Kab-Kooler, incorporates all components of the refrigeration system including a 4.25-hp gasoline or propane engine in a single housing which is 29 in. square and 19 in. high. Only necessary components not part of the unit are starting batteries, fuel tank and fuel pump. Controls are mounted on an air housing which projects into the cab or space to be cooled. The housing provides two cold air outlets and a return duct. Suggested applications for the unit include small panel truck bodies, display vans, work boats and pleasure craft, as well as truck cabs, cranes and power shovels.



Dial-Spindle Lathe Is Two Machines in One

INCORPORATION of two spindles in a single lathe makes it virtually two machines in one. Recently introduced by Boye & Emmes Machine Tool Co., the lathe provides a swing over the bed of 60 in. for the upper spindle and 40 in. for the lower. This feature makes setup and operation of the machine much simpler when the large swing is not required. Additionally, it increases versatility of the machine because work may be held stationary between the upper spindles while an attachment mounted on the carriage performs milling or grinding operations along the entire length of the work piece. Beds may be of any required length.

A new approach to the optimum design of

Thermostatic Bimetal Elements

By C. F. Alban and C. C. Perry

Chief Eng., W. M. Chace Co., Detroit

Research Consultant, Royal Oak, Mich.

THERMOSTATIC bimetal is a unique material, requiring rather special design techniques. It is more than just a material—every length of it is a complete, self-contained transducing system, capable of transforming heat directly into proportional mechanical energy for control, indicating, or monitoring purposes. The design of a bimetal element should be undertaken with the goal of arriving at a unit which is functionally adequate, but which does not waste material. This article will describe several of the newer approaches developed for the optimum design of bimetal elements.

The Specific Deflection Concept: Among the subjects discussed in this article are design methods for obtaining bimetal elements in which the volume, thickness, length, or width is minimized. The understanding of these methods and, as a matter of fact, of the entire technology of bimetals, is aided by the new concept of *specific deflection*.

Specific deflection, or more precisely, specific thermal deflection, is defined as the ratio of the actual deflection or rotation of a bimetal element under any given conditions of temperature change and applied load, to the free (unrestrained) deflection or rotation which the same bimetal element would exhibit for the same temperature change, Fig. 1.

Algebraically (see Nomenclature),

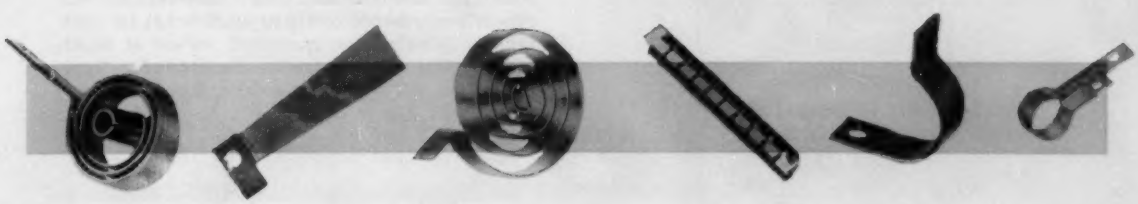
$$m = \frac{D}{D_F}$$

or,

$$m = \frac{A}{A_F}$$

This dimensionless ratio represents a generalized parameter of bimetal performance. As such, it will be found a very convenient tool for design or theoretical calculations on thermostatic-bimetal behavior.

The specific-deflection concept, while new in



form, is not a complete departure from former practices. For example, a rather common problem in bimetal design is represented by an element which must, for a given temperature change, undergo a certain deflection while generating a desired force. In the past, the procedure for treating this type of problem involved picturing the total temperature change as somehow "split," part of it effecting the required deflection and the remainder generating the force. The so-called temperature split for any particular case such as this is always numerically equal to the specific deflection.

The notable advantage in using the specific-deflection concept arises from freeing one's thinking from the hobble of the synthetic division of temperature change. Although working in terms of temperature split has sometimes been useful in visualizing the performance of bimetal elements in simple situations, this approach describes a purely fictional effect and distinctly limits the analytical processes by its lack of reality. In contrast, the specific deflection characterizes a physically observable generality and as a result is capable of greatly extending insight into bimetal technology.

The specific-deflection concept is applicable to all bimetal problems involving a temperature change. If there is no temperature change, the magnitude of the specific deflection is indeterminate and, incidentally, the bimetal is acting just the same as any high quality spring. The discussion here will be restricted to the significant cases in which there is a temperature change and in which the bimetal is functioning in its normal mode.

When the bimetal element is left unrestrained during a temperature change, the force generated is zero, the actual deflection corresponds to the free deflection, and the specific deflection, m, takes the value of unity. If the element is completely restrained during the temperature change, the motion is zero, the force generated is maximum, and the specific deflection is zero. Between these two extremes any combination of deflection and force can be obtained, resulting in corresponding values of specific deflection between zero and unity as shown in Fig. 1*d*.

Following are the equations, incorporating specific deflection, for designing basic bimetal forms such as cantilever-mounted straight strips, and

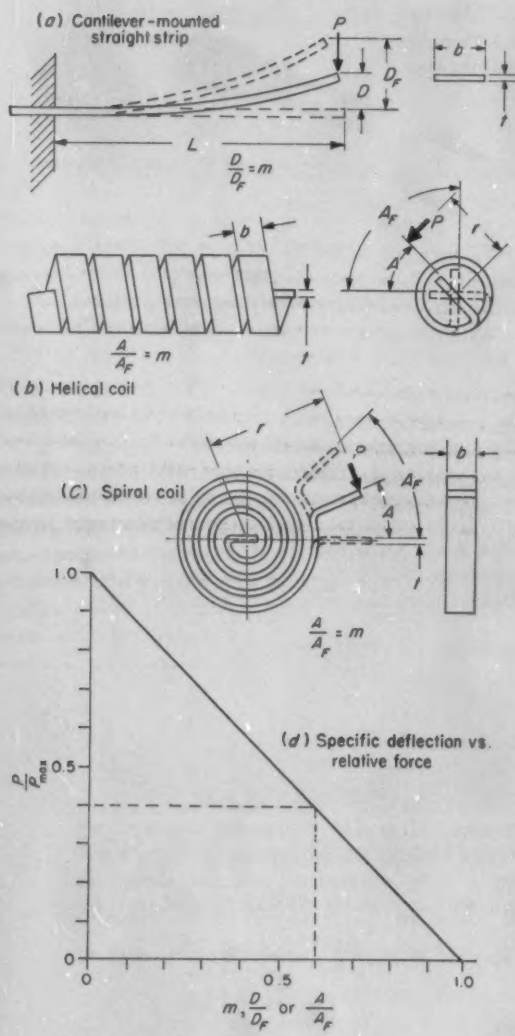


Fig. 1—Types of bimetal elements with nomenclature.

Nomenclature

A	= Rotation, deg (coils)
A_F	= Free (unrestrained) rotation, deg (coils)
b	= Width, in.
D	= Deflection, in. (strips)
D_F	= Free (unrestrained) deflection, in. (strips)
K_{DC}	= Deflection constant (coils)
K_{DS}	= Deflection constant (strips)
K_{PC}	= Torque constant (coils)
K_{PS}	= Torque constant (strips)
L	= Length, in.
m	= Specific deflection, dimensionless
P	= Force or load, oz
r	= Radius to point of load application, in. (coils)
ΔT	= Temperature change, deg F
t	= Thickness, in.
V	= Volume, cu in.

Note: The deflection and torque constants are empirical performance coefficients, different for each type of bimetal, the numerical values of which are supplied by the bimetal manufacturer. Typical values for one thermostatic bimetal (Chace 6650) are: $K_{DS} = 112 \times 10^{-7}$, $K_{PS} = 8 \times 10^{7}$, $K_{DC} = 140 \times 10^{-5}$, $K_{PC} = 4.7 \times 10^{5}$.

spiral and helical coils.

Cantilever strips:

$$D = \frac{K_{DS}(\Delta T)L^2 m}{t} \quad (1)$$

$$P = \frac{K_{PS} D b t^3 (1-m)}{L^2 m} \quad (2)$$

$$P = \frac{K_{PS} K_{DS}(\Delta T) b t^2 (1-m)}{L} \quad (3)$$

Spiral and helical coils:

$$A = \frac{K_{DC}(\Delta T) L m}{t} \quad (4)$$

$$P = \frac{K_{PC} A b t^3 (1-m)}{L r m} \quad (5)$$

$$P = \frac{K_{PC} K_{DC}(\Delta T) b t^2 (1-m)}{r} \quad (6)$$

Optimizing Bimetal Dimensions: Since specific deflection m appears in both the force and the deflection equations, the selection of this parameter for any particular design condition affects the dimensions and proportions of the element. As an example, in the general case of a bimetal element which is to generate a force and produce a displacement simultaneously, the element having the least volume would ordinarily result in the lowest cost. The volume of the element required to meet a particular set of performance specifications in terms of load and deflection is a function of the specific deflection. The relationship between volume and specific deflection can be derived in the following manner:

Multiplying the numerator and denominator of Equation 3 by L gives

$$P = \frac{K_{PS} K_{DS}(\Delta T)(1-m) b t^2 L}{L^2}$$

or,

$$P = \frac{K_{PS} K_{DS}(\Delta T)(1-m) V t}{L^2}$$

From Equation 1

$$\frac{t}{L^2} = \frac{K_{DS}(\Delta T) m}{D}$$

Then

$$P = \frac{K_{PS}(K_{DS})^2(\Delta T)^2(1-m) m V}{D}$$

and

$$V = \frac{PD}{K_{PS}(K_{DS})^2(\Delta T)^2(1-m)m}$$

Differentiating with respect to m and setting the result equal to zero to obtain a minimum,

$$\frac{dV}{dm} = 0 = \frac{PD(1-2m)}{K_{PS}(K_{DS})^2(\Delta T)^2(1-m)^2 m^2}$$

or

$$\frac{1-2m}{(1-m)^2 m^2} = 0$$

and

$$m = 0.5$$

This procedure, which could also have been followed for Equations 4 and 6 with the same result, demonstrates that selecting $m = 0.5$ produces

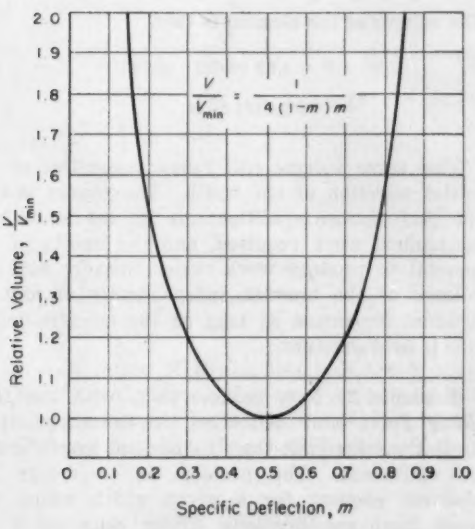


Fig. 2 — Relationship between relative volume of bimetal element and specific deflection.

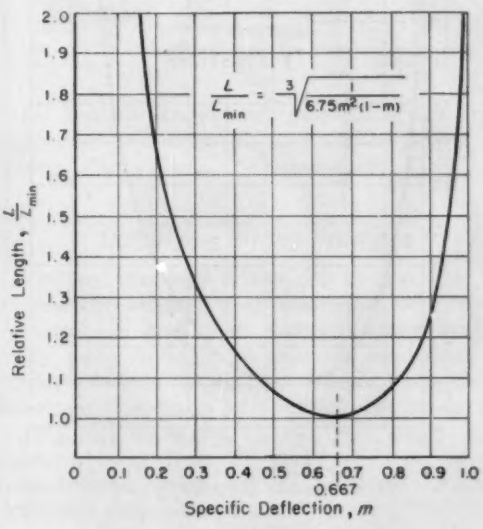


Fig. 3 — Relationship between relative length of bimetal element and specific deflection.

a bimetal element having the minimum total volume. In other words, the most efficient bimetal element is that one in which the design or working deflection when generating the specified force is equal to one-half of the free deflection for the available temperature change. Fig. 2 illustrates the manner in which relative bimetal volume varies with specific deflection. This figure, which holds equally well for straight strips, coils, and U-shaped elements, clearly indicates the economic advantage to be derived from maintaining the specific deflection at 0.5.

Similar analyses can be performed for individual bimetal dimensions such as length, thickness, and width. There may be occasions, for instance, when the bimetal element must be made as short as possible because of space limitations. Fig. 3 illustrates the relationship between relative length and specific deflection. Minimum length for a particular width will result from the selection of $m = 0.667$ for both strips and coils.

For fabricating or other reasons, it may be desirable to control the thickness of the element. In Fig. 4 is plotted the relative thickness versus specific deflection for straight strips only. Minimum thickness for any initially selected width occurs when $m = 0.333$. It will be found that in the case of coils there is no minimum other than that determined by practical considerations of over-all coil rigidity. If for any reason it should be advantageous to minimize the width, a value of $m = 0.667$ will produce an element of minimum width for a particular length and $m = 0.333$ minimum width for a given thickness.

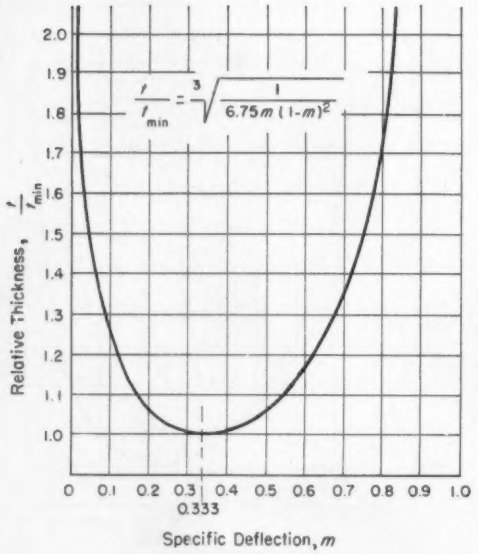


Fig. 4—Relationship between relative thickness of bimetal element and specific deflection for straight strips only.

Example 1: Assume that a cantilever-mounted straight strip bimetal element is to lift a 5-oz weight 0.2-in. over a temperature change of 200 deg F. The problem is to design a bimetal element of minimum volume for performing this operation. From Equation 3,

$$P = \frac{K_{PS}\, Dbt^3(1-m)}{L^3 m}$$

Solving Equation 1 for t, and substituting,

$$t = \frac{K_{DS}(\Delta T)L^2 m}{D} \qquad (7)$$

$$P = \frac{K_{PS}(K_{DS})^3(\Delta T)^3 L^3 bm^2(1-m)}{D^2}$$

or,

$$L = \sqrt[3]{\frac{PD^2}{K_{PS}(K_{DS})^3(\Delta T)^3 bm^2(1-m)}} \qquad (8)$$

Arbitrarily taking a width of 0.25-in, setting the specific deflection at 0.5 for minimum bimetal volume, and inserting torque and deflection constants noted in the Nomenclature yield:

$$L = \sqrt[3]{\frac{5(0.2)^2}{(8\times10^7)(112\times10^{-7})^3(200)^3(0.25)(0.5)^2(1-0.5)}}$$

$= 1.92$ in. active length

Substituting the result into Equation 7 gives

$$t = \frac{(112\times10^{-7})(200)(1.92)^2(0.5)}{0.2}$$

$= 0.021$-in.

The volume of the element is then

$$V = 1.92\,(0.021)\,(0.25)$$

$= 0.0101$ cu in.

This same volume will result regardless of the initial selection of the width. The reason is that the performance specifications fix the amount of mechanical work required, and the ability of the bimetal to produce work varies linearly with the volume of the bimetal, independently of any individual dimension so long as the specific deflection is held constant.

Example 2: Now assume that, with the foregoing force and deflection requirements, space limitations are such that the bimetal length should be minimized. The problem is to design the shortest element for a given width which will meet these specifications. Using Equation 8 and substituting all of the same values except for m which, from Fig. 3, should be 0.667 in order to minimize the length,

$L = 1.82$ in active length

$t = 0.025$-in.

$V = 1.82\ (0.025)\ (0.25)$

$= 0.0114$ cu in.

Thus the length has been reduced to a minimum at the expense of a 10 per cent increase in volume. In this case selection of a different width will alter the minimum length obtainable without changing the total volume of bimetal used. For example, if $b = 0.5$, then $L = 1.44$ in. active length, $t = 0.016$ in., and $V = 0.0115$ in^3. The minor discrepancies in volume between this case and the previous one arise from rounding the thickness off to the nearest thousandth of an inch.

Example 3: Assume that some design or fabricating problem, the nature of which is incidental to this discussion, is such that a bimetal element of minimum thickness is required. A similar solution can be performed by substituting $m = 0.333$ into Equation 8. Again the minimum obtainable thickness will depend upon the initially selected width, but the volume of bimetal will be unaffected by this choice for any given specific deflection. If the width is set equal to 0.50-in. and the same values as before substituted into Equation 8 (except $m = 0.333$), $L = 1.82$ in. active length, $t = 0.012$-in., and $V = 0.0110$ cu in.

The percentage increase over minimum volume in order to minimize the thickness is the same as that for minimum length, as can be seen from the symmetry of Fig. 2.

The foregoing examples give some indication of the degree of control over bimetal element dimensions, proportions, and volume that can be exercised through the use of the specific-deflection concept. This new analytical tool will also pay significant dividends in time savings resulting from the reduction of trial-and-error design. Although this article has shown the application of the specific-deflection concept to only a few basic bimetal forms, the same general methods can be used to establish rational design procedures for all types of bimetal elements.

Tips and Techniques

Calculating Short Cuts

When performing calculations with numbers very nearly equal to one, that is numbers which might be expressed as $1 \pm e$, where e is quite small compared to one, there are several short cuts which can simplify the calculations. These approximations are valid only where values of e^2 are negligible. The approximations are:

$$(1 \pm e)^n \approx 1 \pm ne \qquad (1)$$

$$\frac{1}{1 \pm e} \approx 1 \mp e \qquad (2)$$

$$\frac{1}{(1 \pm e)^n} \approx 1 \mp ne \qquad (3)$$

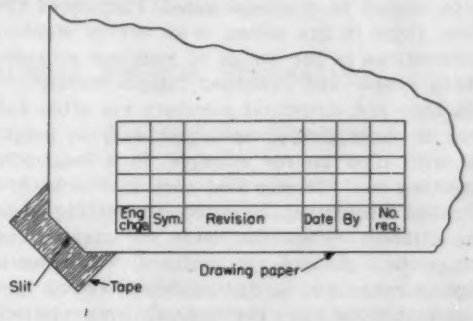
$$\sqrt[n]{1 \pm e} \approx 1 \pm \frac{e}{n} \qquad (4)$$

$$\frac{1}{\sqrt[n]{1 \pm e}} \approx 1 \mp \frac{e}{n} \qquad (5)$$

As an illustration of the accuracy of these methods, when the first method is used to square 1.002, the result is in error by 0.000004.—M. KRAKINOWSKI, *Sonntag Scientific Co., Port Chester, N. Y.*

Taping Drawings

Masking tape is widely used to hold drawings to the board. However, each time the straightedge passes over the tape, it tends to pull the tape loose. By slitting the tape as shown, this trouble is eliminated and the straightedge passes over the drawing corner smoothly.—E. J. KICK, *Columbus McKinnon Chain Corp., Tonawanda, N. Y.*



Simplifying Wiring Drawings

Drafting time and money can be saved by employing this suggestion in connection with wiring drawings. A production wiring diagram may be easily made from the chassis and component assembly drawing by making a sepia print before ballooning the parts and adding the parts list. Wiring is then drawn on the sepia print. It is estimated that from 50 to 70 per cent of the time ordinarily required can be saved.—SAMUEL GOLDRING, *Dorchester, Mass.*

Do you have a helpful tip or technique for our other readers? You'll receive ten dollars or more for each published contribution. Send a short description plus drawings, tables or photos to: Tips and Techniques Editor, MACHINE DESIGN, Penton Bldg., Cleveland 13, O.

Significance of material

Design for Fatigue

By Joseph Marin

Professor and Head, Dept. of Engineering Mechanics
Pennsylvania State University, University Park, Pa.

EXPERIENCE shows that fatigue failure is usually due to poor design, seldom to faulty material.[23] The importance of providing for combined stresses, including stress-concentration effects, cannot be overemphasized. Purpose of this article, third in the series, is to review strength considerations in the design of members subjected to both simple and combined fatigue stresses.

Machine and structural members are often subjected to loads and stresses that vary in magnitude with time as, for example, in a locomotive connecting rod. Stresses that vary in this manner are called fluctuating, repeated, alternating or fatigue stresses. When the loads are applied suddenly, impact stresses are produced. Two types of fatigue stresses can be distinguished: In one type, stress variations occur continuously over relatively long periods of time as, for example, in railway axles, crankshafts, connecting rods of engines and turbine shafts; in the second type, stress fluctuations occur for only a fraction of the life of the structure. In this latter type—often encountered in railway bridges, for example—fatigue properties of the material are not important.

Nature of Fatigue

Repeated loading conditions, if applied a sufficiently large number of times, may result in fatigue failure of the material. Such failures are a result of progressive fracture and begin with the gradual spreading of a small crack from a point of high stress until complete rupture of the part is produced. Stress concentrations leading to progressive fracture may result from irregularities of outline as, for example, abrupt changes in cross section or internal flaws. Evidence of incipient failure by fatigue may easily be overlooked, since a small crack responsible for such failure might not be detected, even by Magnaflux or X-ray inspection.

Fatigue vs. Static Fractures: The type of fracture produced in ductile materials by fatigue loading differs from that produced by static loading. Under static loading, plastic flow of the material precedes fracture, and the ruptured surface shows a fibrous structure produced by the stretching of the crystals. A fatigue fracture, however, has an entirely different appearance, exhibiting two distinct zones of failure: one produced by gradual development of the crack, and the other produced by sudden fracture. The fractured surface produced by sudden failure resembles that obtained when a brittle material such as cast iron fails under static tensile loading. An important characteristic of fatigue fracture is that, even with the most ductile materials, failure takes place without revealing plastic deformation and generally when the part is stressed below the elastic limit.

Although no completely adequate theory has been formulated to explain fatigue failure,[27-29] the mechanism of such failures is at least partially known. Considerable attention is currently being devoted to the study of crack formation and propagation in fatigue.[24]

Statistical Nature of Failure: Microscopic examination shows that metals have many small cracks oriented in various directions. This random orientation and distribution of cracks accounts for the widely different values of fatigue strength obtained when different test specimens are cut from the same piece of material. Such variations indicate that fatigue strengths should be stated in terms of most probable values. This statistical nature of

[23]References are tabulated at end of article.

properties in

Loading Part 3

Nature of Fatigue
Simple Fatigue Stresses
Complete Reversal
Superimposed Stresses
Varying Stress Amplitude

fatigue has led to the interpretation of fatigue strengths by statistical procedures wherein test data are evaluated in terms of a probable strength, rather than as an exact value. For example, with the statistical method, fatigue strength might be stated as at least 50,000 psi 80 per cent of the time and lower than 50,000 psi for the remaining 20 per cent of the time.

The concept of fatigue failure being dependent upon a crack or "weakest link" is consistent with the fact that the volume of the specimen has an important influence on the fatigue strength. That is, large-sized specimens, with more flaws than smaller specimens, have greater chances of failure because of the larger number of possible sources of failure. This conclusion is confirmed by tests.

Three main methods have been used in investigating the behavior of materials subjected to repeated stresses. One basic approach, as used by Gough and Wood[30], considers the fatigue strength of single crystals. A second approach evaluates strength properties of small specimens made up of aggregates of crystals. The third type of fatigue study determines fatigue strengths of full-scale machine and structural members. The following discussion is confined primarily to the second type of approach.

Simple Fatigue Stresses—

Complete Reversal

Simple fatigue or fluctuating stresses can be represented by those in a bar subjected to a fluctuating axial load, as produced, for example, in a connecting rod. Variation of such a stress with time is shown in Fig. 13*a*. Shape of the stress-time curve will depend upon the type of mechanism producing the stress fluctuations. Most fatigue-testing machines that use constant-speed motors produce the sinusoidal type of stress variation shown in the figure. Regardless of the shape of the stress-time curve, stress in Fig. 13*a* varies

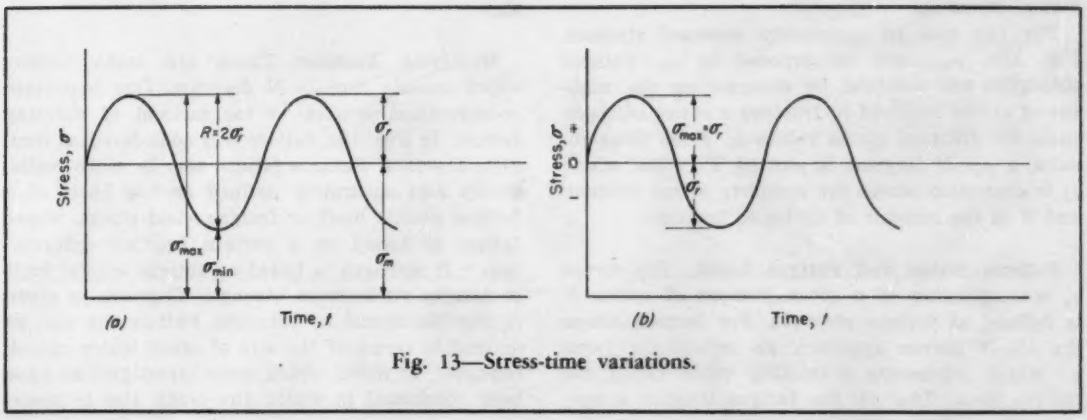


Fig. 13—Stress-time variations.

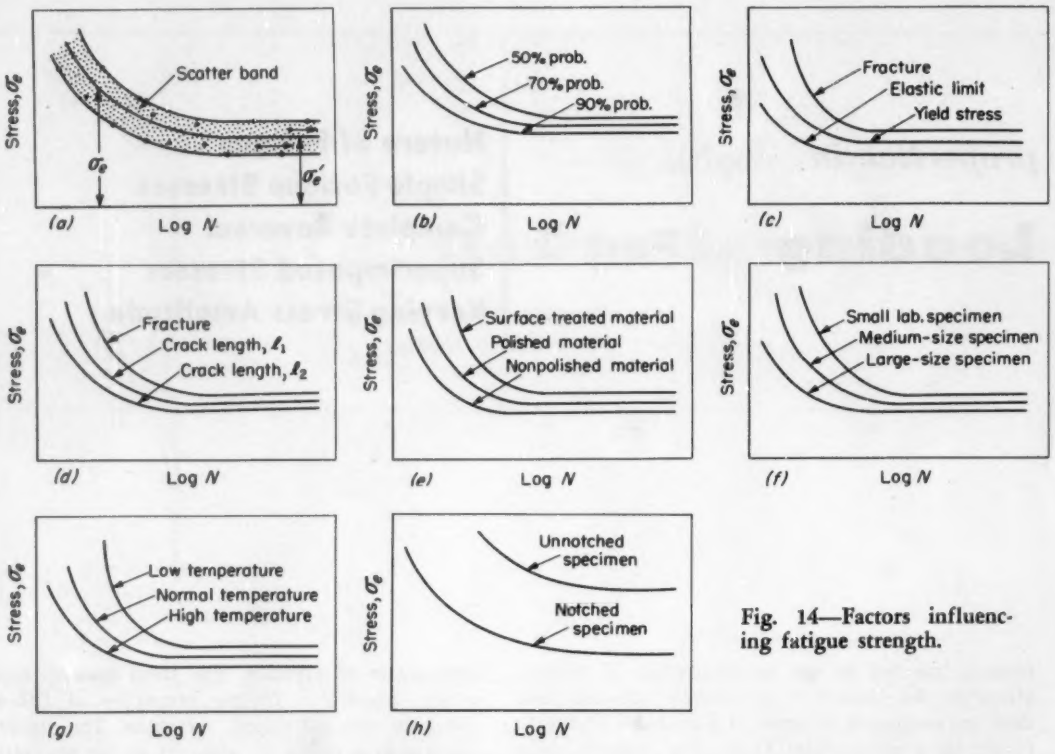


Fig. 14—Factors influencing fatigue strength.

from *maximum stress* σ_{max} to *minimum stress* σ_{min}. Two other stresses indicated are *mean stress* σ_m and *variable stress* σ_r. Values of σ_m and σ_r, in terms of σ_{max} and σ_{min}, are:

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} \tag{38}$$

$$\sigma_r = \frac{\sigma_{max} - \sigma_{min}}{2} \tag{39}$$

Stress variation $R = 2\ \sigma_r$ is called the *range of stress*. Additional fatigue loading symbols and nomenclature are defined in Reference 31. The stress variation in Fig. 13*a* can be considered as a static mean stress σ_m superimposed on a completely reversed stress σ_r.

For the case of completely reversed stresses, Fig. 13*b*, σ_{max} will be denoted by σ_e. Fatigue strengths are obtained by determining the number of cycles required to fracture a series of specimens for different stress values σ_e. From these results, a σ_e—N diagram is plotted, Fig. 14*a*, where σ_e is maximum stress for complete stress reversal and N is the number of cycles to fracture.

Fatigue Stress and Fatigue Limit: The stress σ_e corresponding to a given number of cycles N is defined as *fatigue strength*. For ferrous alloys the σ_e—N curves approach an asymptotic value σ_e' which represents a limiting value called the *fatigue limit*. That is, the fatigue limit is a special value of the fatigue strength corresponding theoretically to an infinite number of cycles or life. Because of the time required to obtain σ_e—N diagrams, Fig. 14*a*, various "rapid fatigue tests" have been proposed.[27] One of these methods (Prot method) shows considerable promise. A number of investigations show that the Prot procedure gives good approximations to the fatigue limit.

Considerable scatter is found in most fatigue-test results. If sufficient tests are conducted, a band represented by the shaded area in Fig. 14*a* is obtained rather than a single line. By statistical methods[28], σ_e—N lines corresponding to certain percentage probabilities of survival can be fixed, Fig. 14*b*. The engineer must then decide which of these lines is to be selected for his particular design.

Modifying Factors: There are many factors which modify the σ_e—N diagram. One important consideration relates to the method of defining failure. In Fig. 14*a*, failure was considered as complete fracture. Fatigue failure may be more realistically and accurately defined on the basis of a fatigue elastic limit or fatigue yield stress, where failure is based on a certain limiting deformation.[32] If strength is based on fatigue elastic limit or fatigue yield stress, strength diagrams as given in Fig. 14*c* would be obtained. Failure can also be defined in terms of the size of crack which can be tolerated. In recent years, some investigations have been conducted in which the crack size is meas-

ured at various time intervals to fracture. On this basis, strength diagrams based on the length of the crack which eventually produces fracture can be obtained, Fig. 14*d*.

There are also a number of material factors, such as surface effects (including surface roughness and residual stresses, corrosion, surface treatment including shot peening, cold working, carburizing and nitriding), which influence fatigue strength values.[23, 33] Fig. 14*e* represents such modifications resulting from material variations.

Differences between sizes of the laboratory specimen and the member to be designed may have a significant effect on the fatigue strength. This subject has recently been reviewed by Horger[34] and Grover et al.[28] Although there is some conflicting information on size effect, it appears that an allowance of 10 to 15 per cent lower fatigue strength for specimens up to 2 in. diameter is reasonable (based on fatigue strengths of laboratory specimens ⅛ to ⅜-in. diameter). For larger sizes, adjustments should be made for further decrease in strength values. Influence of the size effect is shown in Fig. 14*f*.

In addition to size, shape of cross section of the member affects fatigue strength.[28] The influence of elevated temperatures on fatigue strength may also be appreciable.[23, 27] Effect of an increase in temperature is to decrease the fatigue strength, Fig. 14*g*. Determination of fatigue strength at elevated temperatures is complicated by the metallurgical changes in the material which take place at elevated temperature. These changes result in recrystallization, phase changes, precipitation, or diffusion in the material. In the evaluation of fatigue strengths at elevated temperatures, failure by creep must also be considered.[35]

Stress concentrations, such as produced by fillets and grooves, may have an appreciable effect on the fatigue strength, as indicated in Fig. 14*h*. A discussion on stress concentration in fatigue is given in a subsequent article in this series.

In the design of a member to resist fatigue loadings, there are considerations other than those illustrated in Fig. 14. The preceding discussion does not treat all the differences that exist between the laboratory specimen and the structural or machine part. Some of these differences relate to the method of loading. It is recalled that stress amplitude in the foregoing discussion has been considered constant. In many applications, however, a varying stress amplitude occurs, as discussed in a subsequent section. In certain machine and structural parts there is also the possibility of near-resonant loading conditions. It is then necessary to design on a basis of both the fatigue strength and the damping properties of the material.

Design Fatigue Stress: Based on the various factors that influence fatigue strength, σ_e, the following equation can be written for design fatigue stress:

$$\sigma_{ew} = [k_b \times k_c \times k_d \times k_e \times k_f \times k_g \times k_m][k_a]\sigma_e \quad (40)$$

In this expression, k factors provide for the following:

k_b = scatter in data
k_c = allowable deformation
k_d = permissible crack length
k_e = surface treatment
k_f = size effect
k_g = temperature
k_a = stress concentration
k_m = miscellaneous effects

In some design problems, it may be desirable to express the σ_e—N relation by an equation. Various relations have been proposed for this purpose. One approximation proposed by Wiebull[36] defines fatigue strength σ_e for a number of cycles N as

$$N = \alpha(\sigma_e - \sigma_e')^{-\beta} - B \quad (41)$$

where α, β and B are empirical constants, and σ_e' is the fatigue limit.

Another relation proposed by Shanley[37] for materials without fatigue limits is expressed by

$$N = \left(\frac{k}{\sigma_e}\right)^a \quad (42)$$

where k is stress for failure at one complete cycle,

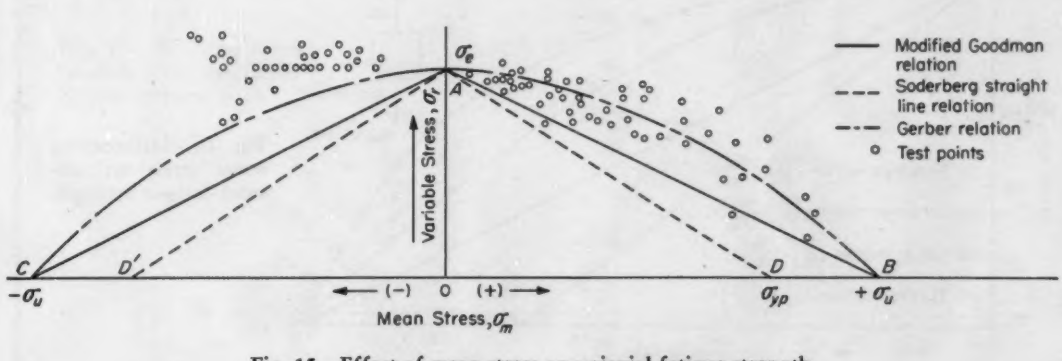


Fig. 15—Effect of mean stress on uniaxial fatigue strength.

and α is an empirical constant.

Working stress can be determined for a specified number of cycles N by using Equation 40 and the value of σ_e as defined by Equations 41 or 42. With the working-stress value known, the required area of the member subjected to reversed fluctuating axial stress can be determined.

Simple Fatigue Stresses—Static Plus Complete Reversal

Completely reversed stresses, Fig. 13*b*, are a special case of fluctuating axial stresses. In general, the type of stress variation shown in Fig. 13*a* exists. This stress variation may be considered as a static mean stress σ_m superimposed upon a variable completely reversed stress σ_r.

To define the fatigue strength for the stress condition shown in Fig. 13*a*, it is necessary to determine the values of σ_r producing failure for various possible values of the mean stress and number of stress cycles. A review of test data on the effect of the mean stress (prior to 1939) was made by Smith.[58] A collection of some data on ductile materials is shown in Fig. 15 in which the variable stress values σ_r are plotted against the mean stress values σ_m for various stress combinations. Since these and other test data do not appear to follow a pattern, several methods of interpretation have been proposed. Three of the most commonly used relations for expressing this type of test data are the Gerber, Modified Goodman, and Soderberg straight-line relations. These relations are plotted in Fig. 15 and can be expressed algebraically in terms of the variable stress σ_r and the mean stress σ_m as follows:

GERBER PARABOLIC RELATION:

$$\frac{\sigma_r}{\sigma_e} + \left(\frac{\sigma_m}{\sigma_u}\right)^2 = 1 \qquad (43)$$

MODIFIED GOODMAN STRAIGHT-LINE RELATION:

$$\frac{\sigma_r}{\sigma_e} + \frac{\sigma_m}{\sigma_u} = 1 \qquad (44)$$

SODERBERG STRAIGHT-LINE RELATION:

$$\frac{\sigma_r}{\sigma_e} + \frac{\sigma_m}{\sigma_{yp}} = 1 \qquad (45)$$

where σ_{yp} = static tensile yield strength, σ_u = static nominal ultimate tensile strength; and σ_e = fatigue strength for completely reversed axial stress.

A relationship between σ_r and σ_m with at least some theoretical basis can be obtained from the assumption that strain energy for completely reversed stresses at N cycles equals strain energy for N cycles when a static mean stress is superimposed on a variable stress. Assuming a sinusoidal variation of stress with time and equating these energies, it can be shown that the failure relation is

$$\left(\frac{\sigma_r}{\sigma_e}\right)^2 + \left(\frac{\sigma_m}{\sigma_u}\right)^2 = 1 \qquad (46)$$

For purposes of comparison, the four relations expressed by Equations 43 through 46 are plotted in Fig. 16.

A relation which expresses all four equations is

$$\left(\frac{\sigma_r}{\sigma_e}\right)^n + \left(\frac{k\,\sigma_m}{\sigma_u}\right)^m = 1 \qquad (47)$$

where n and m are constants for a particular material. For all but the Soderberg relation, $k = 1$, while for the Soderberg equation $k = \sigma_u/\sigma_{yp}$

Working-Stress Relationships: For design purposes, factors of safety must be applied to the failure relations. Then the working stress relation corresponding to Equation 47 can be replaced by

$$\left(\frac{\sigma_r}{\sigma_{we}}\right)^n + \left(\frac{k\,\sigma_m}{\sigma_{wu}}\right)^m = 1 \qquad (48)$$

where $\sigma_{we} = \sigma_e/N_e$, $\sigma_{wu} = \sigma_u/N_u$, and N_e and N_u

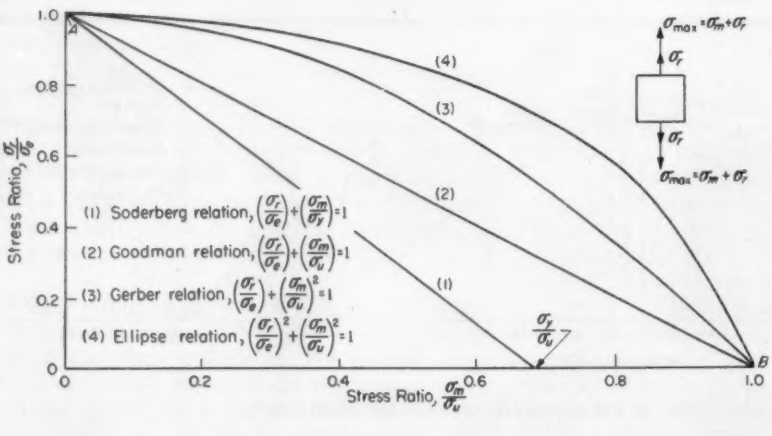


Fig. 16—Influence of mean stress on uniaxial fatigue strength.

are factors of safety.

Based on the Soderberg relation (Equation 45) the working stress relation becomes

$$\frac{\sigma_r}{\sigma_{we}} + \frac{\sigma_m}{\sigma_{wy}} = 1 \qquad (49)$$

where $\sigma_{wy} = \sigma_{yp}/N_y$, and N_y = a factor of safety. Equation 49 is plotted in Fig. 17.

It is sometimes more convenient in design to express Equation 49 in terms of the maximum stress in place of the variable stress. This can be done by substituting $\sigma_r = \sigma_{max} - \sigma_m$. The allowable value of σ_{max} then becomes

$$\sigma_{max} = \left(1 - \frac{\sigma_{we}}{\sigma_{wy}}\right)\sigma_m + \sigma_{we} \qquad (50)$$

In the design of members with stress concentrations subjected to fluctuating axial stress, design relations such as Equation 49 must be modified. Methods for doing this are explained in a subsequent section.

Most designers determine working stresses in fatigue by using the Modified Goodman or Soderberg relations, Equations 45 or 46. It should be noted that inconsistencies are introduced when these failure relations are used. If the Modified Goodman relation is used, then point *A*, Fig. 16, representing failure for complete stress reversal usually represents failure by fracture, while point *B*, representing static tensile failure, does not correspond to fracture but to the ultimate nominal stress. When the Soderberg relation is used, inconsistencies also exist because the yield stress is taken as the failure stress for static stresses, while failure for completely reversed stresses is defined by fracture. Between the extreme cases of completely reversed stresses and static stress only, neither the Modified Goodman nor the Soderberg relations define failure on any consistent definition of what constitutes failure. It should also be noted that fracture is the basis used for defining failure in the tests reported in Fig. 15, with some values of the maximum stress σ_{max} falling below the yield stress and some above.

Mean-Variable Stress Relationship: Some of the foregoing inconsistencies have been noted in References 29 and 32, and corrected procedures have been suggested. Kawamoto and Nishioka[32] determine deformations during fatigue tests for the purpose of finding the fatigue-elastic and yield stresses. Their tests show that the fatigue-elastic and yield stresses are not equal to those for static stress. For this reason it is proposed that the mean-variable stress failure relation be expressed by the equations that follow.

FOR MATERIAL WITHOUT A YIELD POINT:

$$A'\left[\sigma_m + \alpha'\left(\frac{\sigma_m}{\sigma_{yp}}\right)^{q'}\sigma_r - \sigma_{yp}\right]^{n'} + \epsilon_{yp} = \epsilon_f \qquad (51)$$

where A', α', q' and n' = empirical constants; ϵ_f = permanent strain due to fatigue; and ϵ_{yp} = plastic strain at the static yield stress.

FOR MATERIALS WITH A YIELD POINT:

$$A\left[\sigma_m + \alpha\left(\frac{\sigma_m}{\sigma_p}\right)^{q}\sigma_r - \sigma_p\right]^{n} = \epsilon_f \qquad (52)$$

where A, α, q and n = empirical constants; and σ_p = elastic limit in fatigue.

With $\epsilon_f = 0$ substituted in Equation 52, the relation where permanent deformation in fatigue begins is

$$\sigma_m + \alpha\left(\frac{\sigma_m}{\sigma_p}\right)^{q}\sigma_r - \sigma_p = 0 \qquad (53)$$

Plastic-Deformation Stress Relationship: Another procedure for defining fatigue would be to define failure stresses σ_e' and σ_t on a basis of a specified plastic axial deformation. These failure stresses are denoted by points *A* and *B* in Fig. 18. Test results for stress combinations between *A* and *B* are then approximated by the following relation:

$$\left(\frac{\sigma_r}{\sigma_e'}\right)^{n} + \left(\frac{\sigma_m}{\sigma_t}\right)^{m} = 1 \qquad (54)$$

Determination of failure in fatigue can also

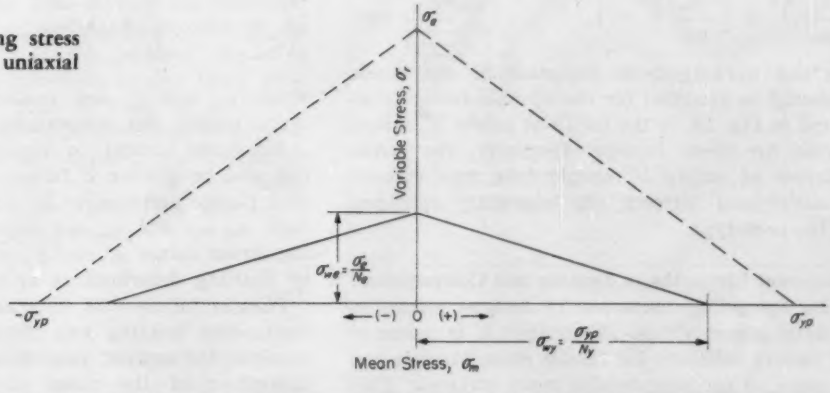


Fig. 17—Working stress relation for uniaxial fatigue stresses.

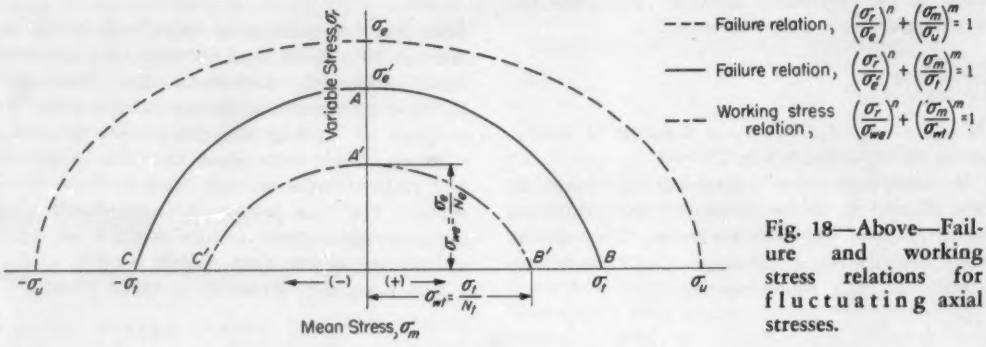


Fig. 18—Above—Failure and working stress relations for fluctuating axial stresses.

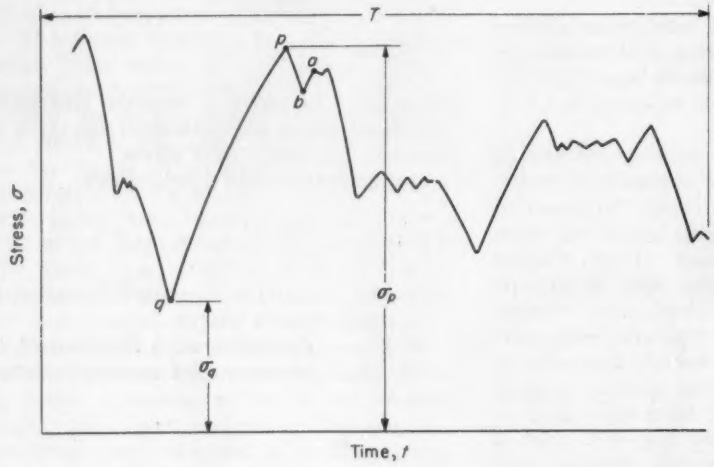


Fig. 19—Left—Stress-time variation.

be based on a limiting size of crack—perhaps one specified by the length of the largest crack. With this basis for failure, σ_e', Equation 54, would then become the stress corresponding to a crack of specified size, while σ_t would be a static strength of corresponding severity.

To determine a working stress relation corresponding to Equation 54, it is only necessary to replace the strength values σ_e' and σ_t by allowable values $\sigma_{we} = \sigma_e'/N_e$ and $\sigma_{wt} = \sigma_t/N_t$, respectively. Then the working stress relation for uniaxial fluctuating stress becomes

$$\left(\frac{\sigma_r}{\sigma_{we}}\right)^n + \left(\frac{\sigma_m}{\sigma_{wt}}\right)^m = 1 \qquad (55)$$

In the working-stress Equation 55 the stress σ_e' should be modified for the various factors considered in Fig. 15, or the factor of safety N_e should provide for these factors. Similarly, the stress or factor of safety N_t should take into account the differences between the laboratory specimen and the prototype.

Different Strengths in Tension and Compression: In the foregoing discussion of fatigue strengths for axial stress (Figs. 15 to 18), it is assumed that failure relations for tensile mean stresses are the same as for compressive mean stresses. This assumption will give results on the safe side, as indicated by the test results in Fig. 15. However, if a more accurate representation of the test data is desired, then two different failure relations can be used, depending upon whether σ_m is a tensile or a compressive stress. The failure relation based on Equation 47 would become:

FOR σ_m TENSILE:

$$\left(\frac{\sigma_r}{\sigma_e}\right)^{n_t} + \left(\frac{\sigma_m}{\sigma_{ut}}\right)^{m_t} = 1 \qquad (56.1)$$

FOR σ_m COMPRESSIVE:

$$\left(\frac{\sigma_r}{\sigma_e}\right)^{n_c} + \left(\frac{\sigma_m}{\sigma_{uc}}\right)^{m_c} = 1 \qquad (56.2)$$

where σ_{ut} and σ_{uc} are, respectively, the ultimate static tensile and compressive strengths.

Equations similar to Equations 56.1 and 56.2 can also be written if failure is based on a specified plastic deformation or size of crack. In this case, σ_e, σ_{ut} and σ_{uc} are replaced by corresponding stress values σ_e' and σ_t, which are determined by limiting deformations or crack sizes.

Fatigue failure test data are also obtained for fluctuating bending and torsion. Although it is possible to express empirical relations defining the effect of the mean stress on the fatigue

strength for these types of load, the variation in the stress over the cross section complicates the interpretation of these strength results. Usually the plotted values of strengths in bending and torsion are determined by the "elastic" theory. However, where plastic flow occurs, the stresses are redistributed and cannot be calculated by the elastic theory.

The uniaxial fatigue relations expressed in this article can now be used to define fatigue failure under combined states of stress.

Simple Fatigue Stresses—Varying Stress Amplitude

Parts used in service are not always subjected to the same stress cycle as shown in Fig. 13*a* but may have stresses applied as indicated in Fig. 19. For example, automobile springs are subjected to various stress levels during operation, aircraft structures undergo many kinds of gust loads, and machinery is subjected to varying stresses by transient vibrations. Under these conditions of loading the σ_a—N curve cannot be used directly for determination of fatigue strength or the life of a part.

When stresses are applied under conditions of varying stress amplitude, the question is raised as to the fatigue damage produced in a material by cycles of high stresses. In other words, how is the life of a part influenced by a certain number of stress cycles higher or lower than the average stress applied? Stressing at low stress levels has sometimes produced beneficial effects of strengthening as a result of work hardening. Overstressing, on the other hand, may considerably reduce the subsequent fatigue strength at lower stress levels.

A large number of experimental studies have been made to determine the influence of varying stress amplitudes on the fatigue strength and life of materials. References 39, 42, 43 and 44 cover several experimental investigations on cumulative fatigue damage. Methods for interpreting fatigue damage and life under varying stress amplitudes have been proposed by several investigators (References 39, 40, 41, 47 and 48).

The most commonly used method for determining fatigue life under varying amplitudes is one proposed by Miner.[39] In this method, life of a specimen or part is governed by the cycle ratio at that stress level. That is, if σ_a, σ_b, σ_c . . . σ_n are the various stress levels that may be applied, N_a, N_b, . . . N_n are the stress cycles applied at each stress level, and N_{ao}, N_{bo}, . . . N_{no} the stress cycles required to produce fracture for each stress level, then by Miner's hypothesis,

$$\frac{N_a}{N_{ao}} + \frac{N_b}{N_{bo}} + \frac{N_c}{N_{co}} + \ldots + \frac{N_n}{N_{no}} = 1 \qquad (57)$$

Although Equation 57 is often used by designers to predict fatigue life, test results show that it sometimes gives only a rough approximation of the test data. In view of the lack of experimental information available, it appears that methods of interpretation such as those given in References 45, 47 and 48 are unnecessarily complicated. A simplified method of intepretation proposed by the author is outlined for uniaxial stresses in the following section.[50]

Fatigue Stress with Varying Load Amplitude: To interpret varying amplitude fatigue stress conditions as shown in Fig. 19, it will first be assumed that the stress pattern shown in Fig. 19 repeats itself a number of times. In other words, Fig. 19 represents a typical stress variation for a time T. To reduce the stress variation of Fig. 19 to an equivalent completely reversed stress of constant amplitude, the following steps are taken:

STEP 1: Small stress variations as, for example, *ab* in Fig. 19, which represent a small fraction (say 2 per cent) of the average stress, will be neglected.

STEP 2: The stress variation for 1/2 stress cycle as, for example, *pq*, will be replaced by 1/2 stress cycle with a mean stress equal to zero. This can be done by assuming the following straight-

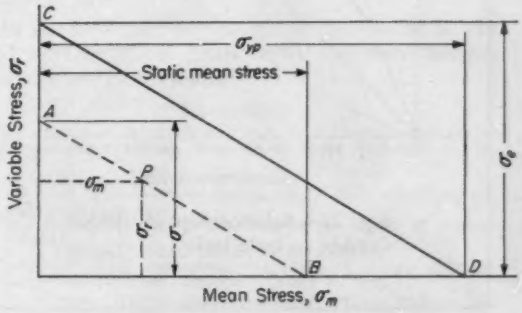


Fig. 20—Determination of equivalent variable stress values.

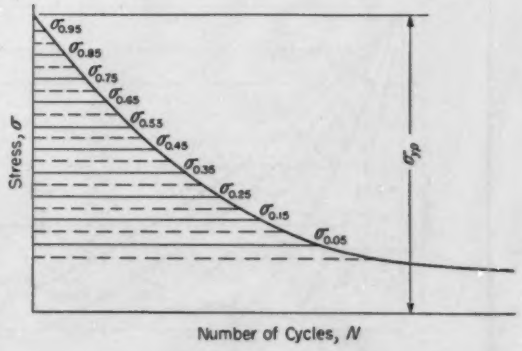


Fig. 21—The σ_a-N relation.

line relation, Fig. 20:

$$\sigma = \sigma_r + \left(\frac{\sigma_e}{\sigma_{yp}} \right) \sigma_m \qquad (58)$$

where

$$\sigma_m = \frac{\sigma_p + \sigma_q}{2}$$

$$\sigma_r = \frac{\sigma_p - \sigma_q}{2}$$

and σ_{yp} = failure stress in simple tension based on a limiting deformation, or yield stress; σ_e = fatigue strength for complete reversal based on a limiting deformation or crack size.

In Fig. 20, AB is drawn parallel to CD. From Fig. 19 and Equation 58, it is now possible to determine a series of σ values for each 1/2 cycle.

STEP 3: Since there would obviously be a large number of σ values obtained when the above procedure is used, it will be assumed that an equivalent number of σ values can be used by selecting the stress falling within each interval as the average for the interval. If, for example, the stress between the yield stress and endurance limit as shown in Fig. 21 is divided into ten equal intervals, then for all stress values σ in the seventh interval above σ_e, the value of σ designated for these stresses will be assumed to be $\sigma_{0.75}$. In this way, a series of ten completely reversed stresses, each applied a specific number of times, is obtained.

STEP 4: From the data in STEP 3, the percentage of fatigue life expended can now be obtained. That is, the number of stress cycles that can be applied before failure occurs can be determined. To do this requires a consideration of the damage produced in a material by a specific number of stress cycles of known values. The damage produced will depend not only on the number of stress cycles for each stress value, but also on the order in which these stresses are applied. It has been found that applying the higher stress values first causes more damage than if the lower stress values are applied first. To be on the safe side it will be assumed that the stress values are applied in descending order of magnitude. To determine the amount of damage produced by a given number of stress cycles of known magnitude requires information from a series of tests. Various theories have been developed for predicting the influence of varying stress amplitudes on the fatigue life and some experimental work has been conducted. A simplified approximate procedure for considering the influence of variable stress amplitude is given by the following method.

To develop a method of determining the influence of varying stress amplitude, a series of tests must be conducted so that the damage-cycle

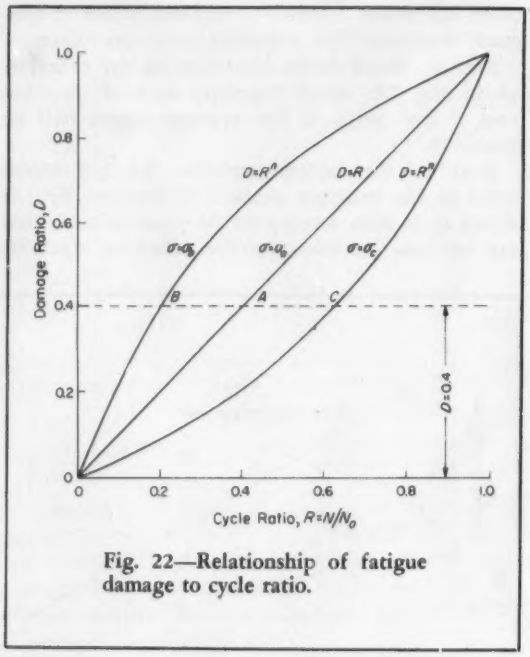


Fig. 22—Relationship of fatigue damage to cycle ratio.

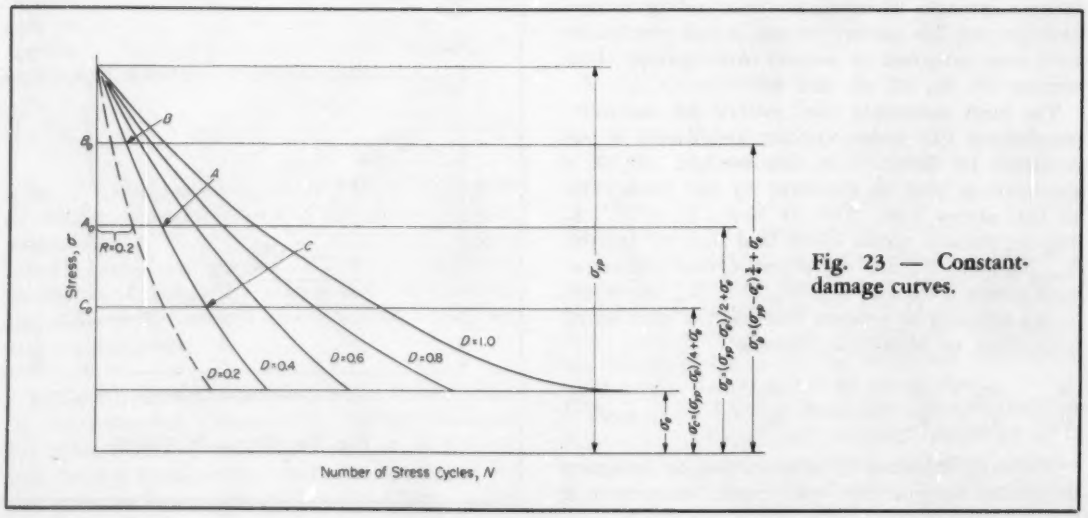


Fig. 23 — Constant-damage curves.

ratio relations can be drawn, Fig. 22. In Fig. 22, $\sigma = \sigma_a$ is the reference stress which, as shown in Fig. 23, can be selected as the average of σ_e and σ_{yp}. That is,

$$\sigma_a = \frac{\sigma_{yp} + \sigma_e}{2} \tag{59}$$

where σ_{yp} = yield strength in tension, and σ_e = fatigue limit for complete stress reversal.

Stresses σ_b and σ_c in Fig. 22 are determined from Fig. 23. These stresses are midway between σ_a and σ_{yp} for σ_b, and midway between σ_a and σ_e for σ_c. Then the values of σ_b and σ_c are

$$\sigma_b = \frac{3\,\sigma_{yp} + \sigma_e}{4} \tag{60.1}$$

$$\sigma_c = \frac{\sigma_{yp} + 3\,\sigma_e}{4} \tag{60.2}$$

Test data provide the basis for finding the D—R curves for $\sigma = \sigma_b$ and $\sigma = \sigma_c$ in Fig. 22. Considering various test data, it is found that the shape of the D—R curves can be expressed approximately by the equation

$$D = R_n \tag{61}$$

where $n < 1$ for $\sigma = \sigma_b > \sigma_a$, and $n > 1$ for $\sigma = \sigma_b < \sigma_a$.

Significance of the curves in Fig. 22 can be explained by first noting that a cycle ratio $R = 0.4$ for $\sigma = \sigma_a$ means that 0.4 of the fatigue life has been expended; that is, since $R = 0.4 = N/N_o$, $N = 0.4N_o$ where N_o is the fatigue life for $\sigma = \sigma_a$. For a value of $R = 0.4$, and for $\sigma = \sigma_a$, the damage ratio corresponds to point A and is $D = 0.4$. Then, point A in Fig. 23 corresponds to point A in Fig. 22. Similarly points B and C in Fig. 22 correspond to points B and C in Fig. 23, and the co-ordinates of points B and C in Fig. 22 can be used to locate points B and C in Fig. 23. The constant-damage curve $D = 0.4$ represented by BAC in Fig. 23 can then be constructed. In the same manner, other constant-damage curves can be drawn as shown in Fig. 23. Significance of the constant-damage curve can be explained by noting the influence of a stress $OB_o = \sigma_b$ applied for a number of stress cycles corresponding to B_oB. Application of this stress is the same for all points on the constant-damage lines BAC. That is, a stress σ_b applied for a number of stress cycles $N = B_oB$ is the same as a stress σ_a applied for a number of stress cycles $N = A_oA$, or a stress σ_c applied for a number of stress cycles $N = C_oC$. In other words, the same damage or reduction in fatigue life is produced by each of these three stress applications.

Fig. 24, as redrawn from Fig. 23, can now be used with STEP 3 to estimate percentage of the fatigue life expended. That is, given the application of stresses $\sigma_{0.95}$, $\sigma_{0.85}$, . . . $\sigma_{0.05}$ for $N_{0.95}$, $N_{0.85}$, . . . $N_{0.05}$ cycles respectively, the dotted lines trace the equivalent stress-time history, ending with point P. Then $PQ = N_f$ represents the fatigue life unexpended for a stress $\sigma = \sigma_{0.05}$. Corresponding life values can be found for other stress values. For example, for a stress σ_a, the unexpended fatigue life is N_f'.

The foregoing method for evaluating fatigue life is based on a number of approximations. However, it is felt that the method represents a rational procedure which is simple to apply.

In the next part of this series, theories of failure and working stress relations for combined fatigue stresses will be presented.

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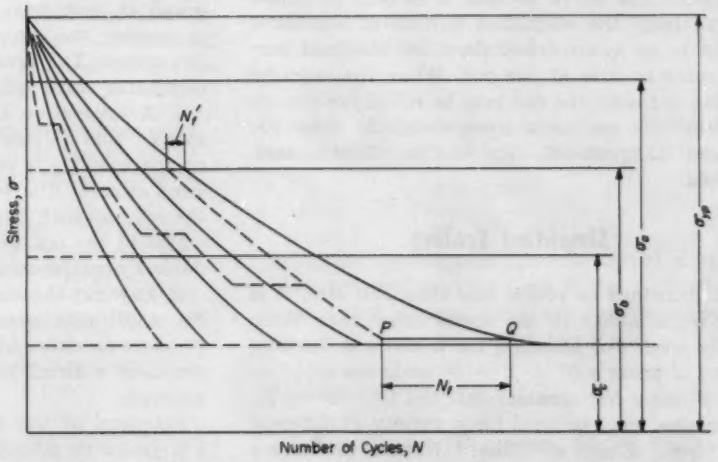

Fig. 24 — Determination of fatigue life.

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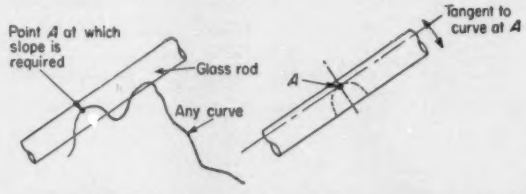
Tips and Techniques

Finding Tangents

Tangents to irregular curves may be found and drawn easily by using a piece of glass rod about ⅜-in. in diameter. The rod is placed on the curve at the point where it is desired to find the tangent. Because of its shape, the rod will magnify and



exaggerate the curve so that it is easy to rotate the rod until the magnified portion of the curve is seen to be symmetrical about an imagined perpendicular to axis of the rod. When the required position is found, the rod may be rolled far enough to permit its use as a straightedge to draw the required tangent.—E. R. PAYNE, *Birmingham, England.*

Simplified Scaling

For drawings to scales less than full size, it is often much easier to use scales other than those usually used. For instance, for a half-size drawing instead of using a 6″ = 1′ − 0″ scale use a ½″ = 1′ − 0″ scale but consider that the 1′ − 0″ = 1″. The method may be used for a variety of different scale sizes, of course.—SIDNEY REIBEL, *estimating engineer, Jervis B. Webb Co., Detroit.*

Subtracting Fractions

There are many systems for subtracting fractions. One which seems to be simpler and faster than most consists of first adding to both fractions the quantity which makes the subtrahend a whole number and then performing the subtraction. For example, to subtract 1 31/32 from 3 7/16, add 1/32 to both and then subtract 2 from 3 15/32.—GEORGE E. PUCKETT, *Canoga Park, Calif.*

Printed Circuit Techniques

When producing an etched circuit by photoengraving methods, a negative or positive is required. The usual procedure is to make a drawing, photograph it, and make either a negative or positive to overlay the sensitized copper-clad plastic as it is exposed. The drawing and photography may be eliminated with either of two methods:

1. A lamination of translucent plastic and red-colored film (Ulano No. 25 Plasti-Cut Foto Mask or equivalent), is placed over a sketch of the desired circuit. The conducting path is cut through the red film with line cutters and circle cutters. Removal of the red film along the circuit paths produces a negative ready for exposure.

2. Lay out the circuit on K & E Stabilene Film No. 130H with pencil, ink, or with W. H. Brady pressure-sensitive connector strips and circles. This produces a direct positive which may be similarly exposed.

Selection of the method depends upon whether a negative or positive is desired.—ALBERT LENDER, *Malden, Mass.*

MACHINE DESIGN
Data Sheet

Practical solution of
CUBIC EQUATIONS

By G. L. Sullivan
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PROBLEMS which involve the response of multiple energy-storage systems frequently require the solution of a third-order differential equation. This means calculating the roots of a cubic characteristic equation or transform. This article presents a brief and direct solution for the cubic equation.

The exact solution[1] is complicated by the many computations and attention to details required to assure sufficiently accurate results. The method of successive approximations[2], Newton's method[2], and other trial and error procedures will produce close results, but the time required depends on how well the person using the method is skilled in its application. Furthermore, these methods are not suitable for the calculation of complex roots. Graeffe's method[2] will produce all roots, but its complexity makes it practical only for higher degree equations.

Shortcomings of the standard methods have led others to publish specialized solutions[3,4] to aid the practicing engineer. These methods, however, require the use of extensive curves or tables in addition to the accomplishment of detailed calculations.

The method described here employs similar initial steps to those for the standard exact solution[1], namely elimination of the second-degree term by substitution, and determination of the nature of the roots from the magnitude of a test ratio. The short cuts are:

1. Only the basic real root need be calculated using formal expressions. The other roots are determined from a simple quadratic expressed in terms of the basic root.
2. When all roots are real, the usual trigonometric solution is replaced by an approximate algebraic equation having excellent accuracy.
3. When a single real root exists, only one, rather than two, cube-root expressions need be evaluated.
4. All equations appear in their most simplified form.

Simplified Solution: The six brief steps required to compute all three roots of the general cubic equation $p^3 + ap^2 + bp + c = 0$ arise from substitution of $p = x - a/3$ to reduce the general cubic to the form $x^3 + 3Nx + 2Q = 0$.

First, calculate the literal portion of the coefficients of the reduced equation using the relationships:

$$N = \frac{b}{3} - \frac{a^2}{9} \tag{1}$$

$$Q = \frac{c}{2} - \frac{ab}{6} + \frac{a^3}{27} \tag{2}$$

Next, calculate the test ratio:

$$K = \frac{N^3}{Q^2} \tag{3}$$

CASE 1: When $1 + K$ is positive (one real root and two complex conjugate roots), or when $1 + K$ is zero (three real roots, two of which are equal), calculate:

$$S = \sqrt[3]{Q\,[1 + (1 + K)^{1/2}]} \tag{4a}$$

Compute the basic real root $p_1 = r$ of the general cubic using the exact equation:

$$r = \frac{N}{S} - S - \frac{a}{3} \tag{5a}$$

CASE 2: When $1 + K$ is negative (three real and unequal roots), calculate:

$$T = \sqrt{-K} \tag{4b}$$

Compute the basic real root $p_1 = r$ of the general cubic using the approximate equation:

$$r = \mp \sqrt{-3N}\left(\frac{T + 0.386}{T + 0.2}\right) - \frac{a}{3} \tag{5b}$$

The ambiguous sign is opposite to the sign of Q.

For either Case 1 or Case 2, the additional two roots of the general cubic are calculated by solving for p using the exact quadratic:

$$p^2 + (a + r)p - \frac{c}{r} = 0 \tag{6}$$

Frequently, p will represent the differential operator d/dt. Then Equation 6 has the alternate

[1]References are tabulated at end of article.

form $p^2 + 2\rho\omega_0 p + \omega_0^2 = 0$, where ω_0 is the undamped natural frequency, and ρ is the damping ratio[5].

Accuracy: The equations are exact for Case 1. For Case 2, an approximate algebraic expression has replaced the unwieldy trigonometric expressions that are employed in the exact solution.

This approximate expression stems from relating the cosine of one-third of an angle to the cosine of the full angle as follows:

$$\cos\frac{\theta}{3} = \frac{\sqrt{3}}{2}\left(\frac{1 + 0.386\cos\theta}{1 + 0.2\cos\theta}\right) \qquad (7)$$

where $0 \leqq \theta \leqq \pi/2$.

To illustrate the accuracy of this relationship, Table 1 shows a comparison between the true values for cos $(\theta/3)$ and the values computed from equation 7.

The greatest error occurring within the table appears at $\theta = 75$ deg and amounts to much less than 0.1 per cent.

The basic real root x_r of the reduced cubic equation $x^3 + 3Nx + 2Q = 0$ will contain the same percentage error that exists in the trigonometric approximation. The basic real root $r = x_r - (a/3)$ of the general cubic equation will contain the same error magnitude as does x_r, but its percentage error will depend on the contribution of the term $-(a/3)$ to the total magnitude of the root.

EXAMPLE 1: Find the roots of this equation:

$$p^3 - 12p^2 + 45p - 104 = 0$$

Here $a = -12$, $b = 45$ and $c = -104$ and, from Equations 1 through 3,

$$N = \frac{45}{3} - \frac{(-12)^2}{9} = -1$$

$$Q = \frac{-104}{2} - \frac{(-12)(45)}{6} + \frac{(-12)^3}{27} = -26$$

$$K = \frac{(-1)^3}{(-26)^2} = \frac{-1}{676}$$

Since $1 + K$ is positive, this solution is as shown in Case 1, Equations 4*a* and 5*a*:

$$S = \sqrt[3]{-26\left[1 + \left(1 + \frac{-1}{676}\right)^{1/2}\right]} = -3.732$$

$$r = \frac{-1}{-3.732} - (-3.732) - \frac{(-12)}{3} = 8$$

This is a correct root. Therefore, in Equation 6:

$$p^2 + [(-12) + 8]\,p - \frac{(-104)}{8} = 0 = p^2 - 4p + 13$$

The quadratic solution gives, correctly:

$$p_2 = 2 + j3,\ p_3 = 2 - j3$$

EXAMPLE 2: Find the roots of this equation:

$$p^3 + 6p^2 - 30p - 40 = 0$$

Here $a = 6$, $b = -30$ and $c = -40$ and, from Equations 1 through 3,

$$N = \frac{-30}{3} - \frac{(6)^2}{9} = -14$$

$$Q = \frac{-40}{2} - \frac{6(-30)}{6} + \frac{(6)^3}{27} = 18$$

$$K = \frac{(-14)^3}{(18)^2} = -8.469$$

Since $1 + K$ is negative, this solution is as shown in Case 2, Equations 4*b* and 5*b*:

$$T = \sqrt{-(-8.469)} = 2.910$$

$$r = -\sqrt{-3(-14)}\left(\frac{2.91 + 0.386}{2.91 + 0.2}\right) - \frac{6}{3} = -8.870$$

Then, substituting these values in Equation 6:

$$p^2 + [6 + (-8.87)]\,p - \frac{(-40)}{(-8.87)} =$$

$$0 = p^2 - 2.87p - 4.510$$

The quadratic solution gives:

$$p_2 = 3.998,\ p_3 = -1.128$$

The correct roots are -8.873, 4.000, and -1.127.

Some who use this method will be tempted to modify Equation 4*a* by multiplying Q into the $1 + K$ radical. Such a change will introduce an ambiguous sign. The converted equation becomes:

$$S = \sqrt[3]{Q \pm (Q^2 + N^3)^{1/2}}$$

where the ambiguous sign is the same as the sign of Q.

Table 1—Accuracy of Equation 7

θ (deg)	cos $(\theta/3)$ Actual	cos $(\theta/3)$ Calculated
0	1.00000	1.00026
15	0.99619	0.99643
30	0.98481	0.98494
45	0.96593	0.96582
60	0.93969	0.93925
75	0.90631	0.90567
90	0.86603	0.86603

Conclusions: This method was devised specifically to allow the direct and accurate calculation of the roots of a cubic equation, eliminating the need for trigonometric tables and superfluous steps.

The relationships are exact, except when all roots are real and unequal. Even then, the accuracy of this method far exceeds the needs of the usual engineering application.

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High-temperature strength characteristics indicate new applications for...

Molybdenum Alloys

By Robert R. Freeman and J. Z. Briggs

Climax Molybdenum Co.
New York

DURING a six-year program sponsored by the Office of Naval Research, molybdenum-base alloys have been developed with much better high-temperature properties than unalloyed molybdenum. These alloys have been found to have higher useful strength at temperatures over 1600 F than any other presently known material. As an indication of the degree of this superiority, Fig. 1 compares the stress-rupture properties of molybdenum and three of its alloys with some of the superalloy materials in current or recent use in the jet-aircraft field.

Four types of arc-cast molybdenum alloys are now commercially available:

0.3 Cb, bal Mo
0.5 Ti, bal Mo
1.0 V, bal Mo
2.0 W, bal Mo

Since the 0.5 per cent Ti molybdenum alloy has shown the best all-around combination of properties, major emphasis here is placed on this grade, its properties and processing. Unless specifically mentioned to the contrary, the discussion is limited to molybdenum made by the arc-cast process. In the jet-propulsion field, all indications point to the predominant use of arc-cast molybdenum rather than the powder-metallurgy product because of the advantages of the former in respect to available sizes, ease of producing alloys, and fabrication characteristics.

Effect of Composition and Processing: The physical properties of molybdenum appear to be little affected either by the small amounts of alloying elements present in current molybdenum alloys or by processing. Of particular significance to the high-temperature field are the high melting point, high thermal conductivity, high modulus values and low expansivity, Table 1. On the other hand, mechanical properties are markedly influenced by composition and processing, Figs. 2 and 3. All three alloys have better stress-rupture and creep strength than unalloyed molybdenum in the same condition, and the 0.5 per cent Ti molybdenum is the best of the alloys.

Processing is also important. The mechanical properties of unalloyed molybdenum depend to a large degree on the amount of mechanical working done below its recrystallization temperature. The presently available molybdenum alloys are similar in that they are not heat-treatable and rely entirely on mechanical working for

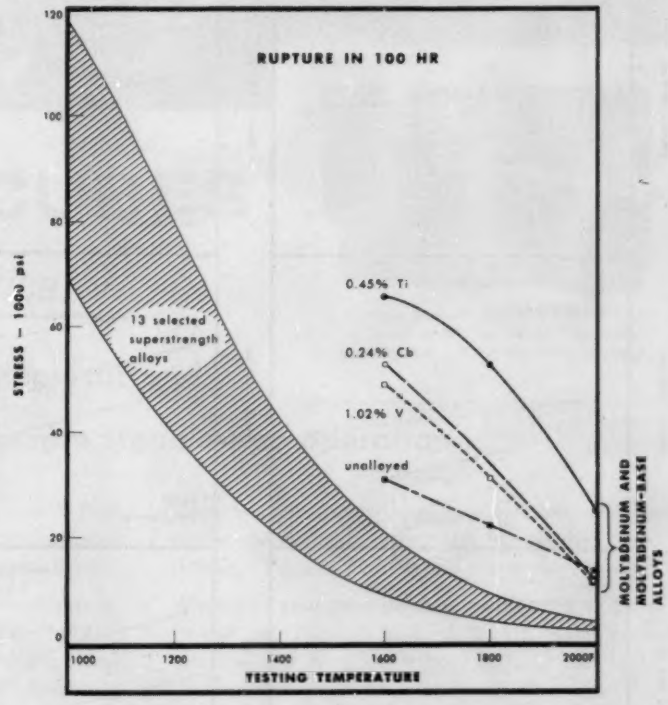

Fig. 1—Stress-rupture strength of molybdenum and three molybdenum-base alloys as compared to the 13 superstrength alloys included in ASTM Special Technical Publication No. 160. Molybdenum and molybdenum-base alloys were produced by arc-casting process and tested after mechanical working and stress relieving.

Table 1—Physical Properties of Molybdenum*

Atomic number	42
Atomic weight	95.95
Crystal structure	Body-centered cubic
Melting point	4730 F
Density at 68 F	0.369 lb/cu in.
Electrical conductivity	
at 32 F	34 per cent IACS
Specific heat at 70 F	0.061 Btu/lb/deg F
Modulus of elasticity (dynamic)	
at 80 F	45.5×10^6 psi
at 1500 F	40.0×10^6 psi
at 2500 F	35.0×10^6 psi
Modulus of rigidity	
at 80 F	17.4×10^6 psi
at 1600 F	15.0×10^6 psi
Poisson's ratio	
at 80 F	0.324
at 1600 F	0.321
Thermal conductivity	
at 70 F	68.2 Btu/hr/sq ft/ft/deg F
at 1650 F	62.4 Btu/hr/sq ft/ft/deg F
Mean coefficient of linear thermal expansion	
at 68 to 212 F	3.06×10^{-6} per deg F
at 68 to 1832 F	3.41×10^{-6} per deg F

*All values determined on unalloyed molybdenum, except thermal conductivity and coefficient of thermal expansion, which were obtained on recrystallized specimens of 0.5 per cent Ti molybdenum alloy.

strengthening. As shown by the data, the high - temperature strength of recrystallized material is significantly lower than that of mechanically worked and stress-relieved specimens of the same grade. At 1600 F, recrystallized specimens have about 40 to 50 per cent lower rupture strength than stress-relieved specimens of the same grade. This difference lessens as the testing temperature increases, and disappears if temperature and time are such that the molybdenum recrystallizes during testing.

The effect of alloying additions on recrystallization temperature is consequently of major significance for high-temperature service as it sets an upper limit to the operating temperatures where mechanical working can be used for strengthening. For 1-in. rounds, previously reduced 91 per cent by rolling, the minimum temperature for complete recrystallization in one hour is raised from 2200 F for unalloyed molydenum to 2600 F for the 0.5 per cent Ti molybdenum alloy.

To summarize, mechanically worked and stress-relieved 0.5 per cent Ti molybdenum alloy has the best high-temperature properties of any of the available molybdenum-base alloys. Additional information on its short-time tensile properties, total deformation and stress-rupture strength is given in Tables 2 and 3, and Fig. 4.

Protective Coatings: If the design permits elimination of oxygen and water vapor from the atmosphere, molybdenum can be used without protection. Despite considerable research, however, no one has yet been able to find a molybdenum alloy that combines high oxidation resistance and good high-

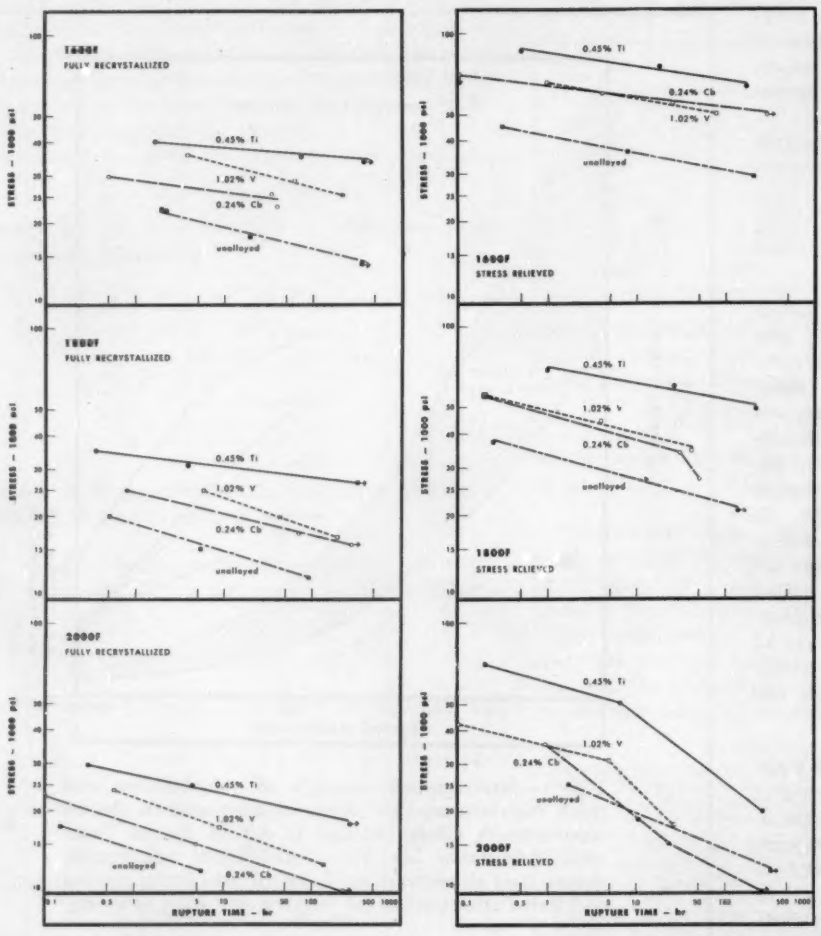

Fig. 2—Stress-rupture strength of molybdenum and three molybdenum-base alloys at 1600, 1800 and 2000 F. Tests were run in vacuum on specimens in stress-relieved and recrystallized conditions.

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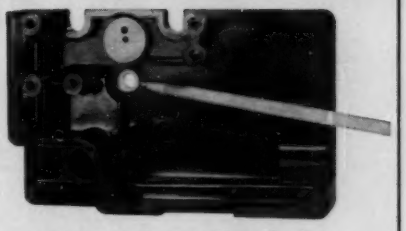

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temperature properties, so this solution must be by-passed for the moment.

Consequently, protective coatings seem to be the answer for most applications. Types of coatings that have been tested have included ceramic, cermet, vapor-deposited, hot-dipped, sprayed metal (metallized), electrodeposited and clad. Some of these coatings have proved successful on a laboratory scale, and commercially feasible solutions to the protection problem appear to be not too far away, especially where a useful life of 500 to 1000 hr at 1800 F (or shorter times at higher temperatures) is considered acceptable.

The specific requirements placed on coatings will vary with the type of part to be protected, but engineers in general are looking for:

1. Adequate oxidation resistance.
2. Absolute integrity of coating.
3. Resistance to thermal shock, impact and erosion.
4. Sufficient ductility to withstand some deformation without damage and, preferably, a certain degree of self-healing for accidental damage.

From the production standpoint, the coating must be capable of:

5. Application to assemblies, complex shapes, edges, hollow parts and large sheets.
6. Withstanding a reasonable amount of handling and flexure in installation.
7. Protection without adding excessive weight or thickness to parts.
8. Giving a smooth finish, either as coated or as ground.
9. Application at temperatures that will not cause recrystallization of the molybdenum if maximum strength and ductility of coated parts are desired. If brazed parts are to be coated, the maximum processing temperature must be adjusted to the filler metal used.

Since no one coating has proved to be best under all conditions, Table 4, the type of coating must be adapted to the service conditions of the part. In addition to the properties listed in Table 4, the sprayed Al-Cr-Si coating has considerable potential at temperatures above 2500 F. Preliminary tests have indicated a life of at least 5 hr at temperatures above 3000 F. Moreover, metal-sprayed specimens have shown practically the same 100-hr stress-rupture strength at 1800 F when tested in air as uncoated specimens tested in vac-

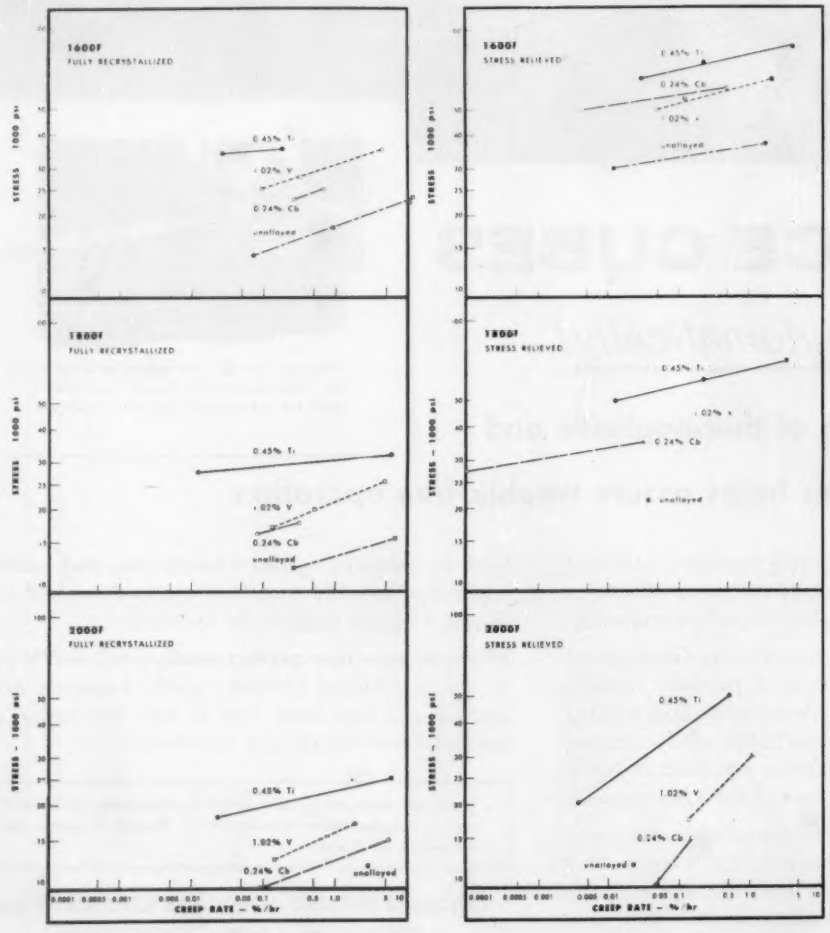

Fig. 3 — Second-stage creep rate of molybdenum and three molybdenum-base alloys at 1600, 1800 and 2000 F. Tests were run in vacuum on specimens in stress-relieved and recrystallized conditions.

BEARING TIPS by McGill

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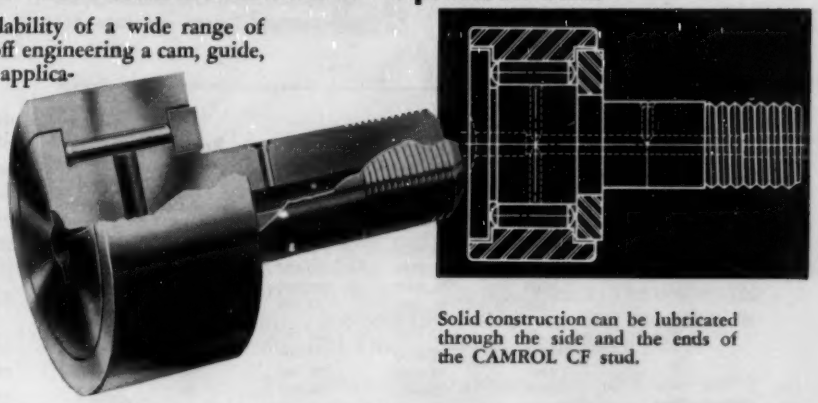
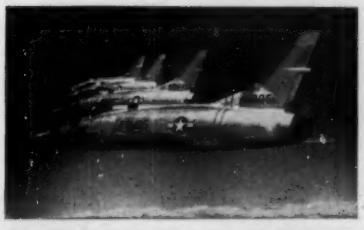


Solid construction can be lubricated through the side and the ends of the CAMROL CF stud.

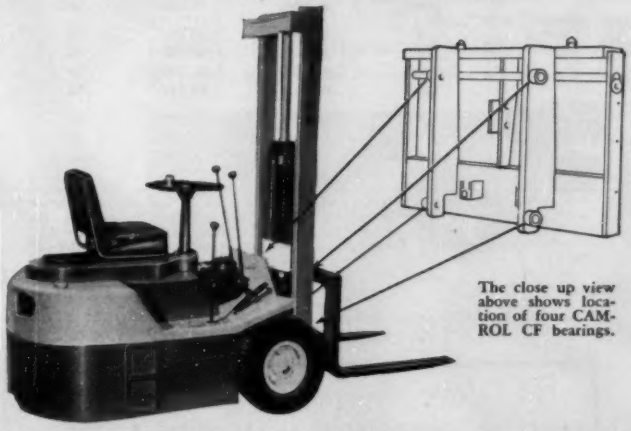
YR bearings help F-100 Super Sabre make slower and safer landing

The supersonic speeds obtained by today's modern aircraft set up design problems not encountered with older, slower planes. The overall streamlined design required for speed in flight, for instance, necessitated finding ways of supporting the North American F-100 Super Sabre at low air speeds required for landing. A



series of slats on the leading edge of the wing, providing greater lift at lower air speed, was the answer. Each slat is supported by McGill CAMROL YR bearings — especially designed to permit shaft or yoke mounting. These long-life bearings carry the loads of these slats as they move on tracks during flight of the Supersonic F-100.

CAMROL CF bearings out-perform friction rollers as fork support bearings



The close up view above shows location of four CAMROL CF bearings.

Small size and high load-carrying unit construction with simplified lubrication are among principal benefits obtained by Hyster Company from use of CAMROL CF bearings as fork support rollers in its Hyster 20 and other lift trucks.

Two bearings ride up and down inside each vertical mast section to position the lift truck fork under load. Speeds are relatively slow but the crushing loads on each bearing are heavy.

In this particular application, the exterior surfaces of the bearings are treated with a black oxide finish. This provides corrosion-resistance which serves to augment maintenance-free operation, a characteristic of CAMROL bearing construction.

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uum. They have also withstood 2 per cent elongation during static loading for 100 and 500 hr at 1800 F without coating failures.

The present status of coatings can be summarized as follows:

1. *Up to* 2000 *F:* Metal cladding for relatively simple shapes where maximum surface toughness is essential. Electrodeposited chromium and nickel-chromium alloys, particularly if complex shapes are involved.
2. *Up to* 2400 *F:* Complex metal-sprayed coatings, which are applicable to relatively large and complex shapes and exhibit some self-healing. These coatings are less brittle than ceramics but less ductile than clad or plated coatings.
3. *Over* 2400 *F:* Encouraging results on some sprayed coatings for relatively short exposures. Ceramic and vapor-deposited molybdenum-disilicide coatings hold promise of long-time protection where service does not involve mechanical impact, high stresses or severe thermal shock.

Table 2—Room and Elevated-Temperature Tensile Properties*
(of 0.5 per cent Ti Molybdenum Alloy)

Bar Diam (in.)	Condition	Testing Temperature (F)	Yield Strength (psi)	Tensile Strength (psi)	Elongation† (per cent)	Reduction of Area (per cent)
¾	As rolled	82	96,700‡	112,900§	29	59.7
		750	78,900‡	100,400	18	76.1
		1200	80,600‡	101,300	18	82.6
		1600	51,000‡	56,900	17	84.0
	Stress relieved 1 hr at 1800 F	80	99,100‡	132,100§	31	70.0
		750	89,000‡	110,000	18	72.8
		1200	84,000‡	100,500	17	74.1
		1600	76,500‡	85,300	15	71.1
	Recrystallized 1 hr at 2450 F	81	60,600	75,500	55	38.0
		750	30,200	45,600	47	86.4
		1200	.....	43,700	45	86.2
		1600	15,400	39,900	47	88.4
1	As rolled	77	89,000‡	115,100	30	46.8
		750	.....	90,800	16	75.5
		1200	68,300‡	84,900	15.5	74.5
		1600	64,800‡	78,400	15.5	75.0
	Stress relieved 1 hr at 1800 F	83	87,900‡	113,000	20	25.4
		750	71,300‡	90,700	17	73.5
		1200	62,600‡	84,700	16	71.9
		1600	62,800‡	77,700	16	75.7
	Recrystallized 1 hr at 2600 F	74	53,900	72,500	22	18.7
		750	11,800	42,400	45	83.9
		1200	10,300	39,200	42.5	87.7
		1600	14,500	37,500	48.5	87.6

*Strain rate 3 per cent per hr within elastic range and 60 per cent per hr within plastic range. †Per cent elongation in 1 in. for 0.250-in. diam test specimen from ¾-in. diam bars; per cent elongation in 2 in. for 0.430-in. diam test specimens from 1-in. diam bars. §Different bars. ‡0.1 per cent offset yield strength taken from stress-strain plot; all other yield-strength values from drop in load.

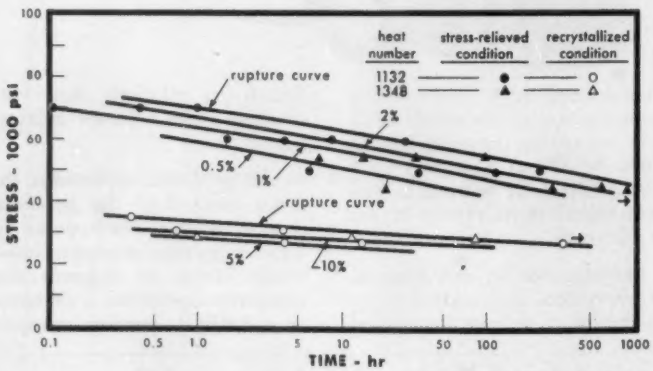

Fig. 4—Relation between stress and time for indicated amounts of total deformation at 1800 F. Tests were run in vacuum on specimens from two heats of 0.5 per cent Ti molybdenum alloy in stress-relieved and recrystallized conditions.

Fabrication and Joining: Molybdenum can be fabricated by most of the conventional methods with little or no modification. All problems connected with joining, however, have not yet been solved, although welds with adequate ductility for many applications can now be produced.

Forging of bar stock is the most suitable way to produce parts such as solid gas-turbine buckets. Because the commercial molybdenum alloys now available are not heat-treatable, the high-temperature strength required for engine operation can be obtained only by warm working below the recrystallization temperature. Close control of both the forging stock and forging operations is necessary.

With sheet up to about 0.020-in. thick, forming, bending, spinning and deep-drawing can be carried out by the usual procedures at room temperature, but it is better practice to heat both the work and tools. Heavier material must be heated to 200 to 1100 F, depending on size. Recent modifications of the spinning process (such as Floturning and Hydrospinning) offer a possibility of forming thin-wall conicals and cylinders without welding or extensive deep-drawing. Room - temperature trials with 1/16-in. thick unalloyed molybdenum resulted in fracture before appreciable forming had been accomplished; successful results,

Table 3—Stress to Produce Rupture in 100 Hours*
(of 0.5 per cent Ti Molybdenum Alloy)

Condition	Stress at 1600 F (psi)	Stress at 1800 F (psi)	Stress at 2000 F (psi)
Stress relieved	66,000	53,000	34,000
Recrystallized	34,500	28,000	21,000

*Values represent averages of closely agreeing figures obtained on two different heats.

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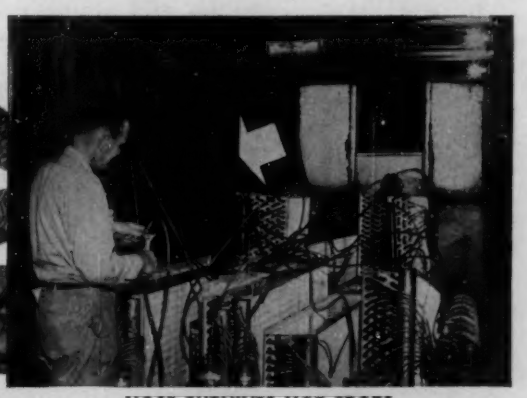

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Philadelphia, Pa. — Briggs Rubber Products Co.
Pittsburgh, Pa. — Shields Rubber Corporation
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St. Louis, Mo. — General Equipment Co.
Toronto, Canada — H. J. Miller Enterprises Ltd.
Wilmington, Del. — Briggs Rubber Products Co.

however, were obtained when the molybdenum was heated to approximately 800 to 1100 F prior to forming, Fig. 5.

Molybdenum and its alloys generally have hardnesses under 300 brinell but are considerably more abrasive to machine than steel at the same hardness. Prior treatment has little effect on machinability. Either high-speed steel or sintered carbide tools can be used for machining; cast cobalt-base alloys have not proved satisfactory. Tool angles and rakes are on the whole similar to those for machining cast iron. A 50-50 mixture of chlorinated oil and trichloroethylene, or highly chlorinated oil is recommended as a cutting fluid.

Arc-cast molybdenum can be welded without porosity and with freedom from cracks. This is generally not true of commercially available molybdenum made by powder-metallurgy methods.

At present, inert-gas shielded arc welding with tungsten electrodes, with or without filler-wire additions, appears to be the most satisfactory method of welding heavy sheets and parts. Straight butt welds are satisfactory for thicknesses up to about 3/32-in. Thicker material will generally require multiple passes in a V-butt joint, with preheat and filler-wire addition. The filler wire obviously lessens the need for highly accurate fit-up.

Welds made under optimum conditions still have poor ductility at room temperature, but bend-test data show significant ductility in the as-welded condition when tested at 300 F or higher. Heating to approximately 500 to 600 F is therefore mandatory when weldments are to be formed or roll-leveled.

Ductility of brazed joints may be superior to welded joints provided the time at temperatures above about 1700 F is kept to a minimum. Brazing, however, is not universally suitable. Moreover, filler alloys adaptable to relatively low-temperature brazing (and which avoid embrittlement of the parent metal) are unsatisfactory for high-temperature applications. Although many brazing alloys have been tried for high-temperature structural applications, and some have given encouraging results for certain parts, Fig. 6, none has as yet proved satisfactory for all applications.

Riveting and other mechanical means of joining offer possibilities for applications that must not be gas or liquid tight. Little has yet been done to determine the feasibility of combinations of mechanical joints (as lock seams) with subsequent brazing or welding.

In summary, there are no insuperable problems in fabricating and joining molybdenum, although more precautions have to be observed than with superalloys. While welds with high ductility at room temperature have not yet been achieved, progress in this direction has been recorded in recent years, and welds with satisfactory properties for many high-temperature applications can now be made commercially.

From a paper entitled "Molybdenum for High Strength at High Temperatures" presented at the American Rocket Society Annual Meeting in New York, November, 1956. *Published in full in* Jet Propulsion, *Vol. 27, February,* 1957.

Table 4—Comparative Performance of Protective Coatings on Molybdenum

Coating	Oxidation Test (minimum life, hr) 1800 F	2000 F	Thermal-Cycling Test (minimum life, cycles)	Ballistic-Impact Test (330 ft/sec) (life at 1800 F after impact, hr)	Erosion Test (life at 1800 F, min)
Sprayed					
Single-layer Al-Cr-Si	500+	100+	484	0	25 to 30
Single-layer Ni-Cr-B	500+	100+	185	500+	55 to 60
Single-layer Ni-Si-B	500+	98	108	500+	40 to 50
Ni-Cr-B + Al-Cr-Si	500+	100+	not tested	22	30 to 55
Al-Si + Al-Cr-Si	500+	100+	476	0	not tested
Electroplated* 0.001-in. Cr + 0.007-in. Ni	500+	114+	130†	500+	not tested

*By National Bureau of Standards. †Separation of nickel from chromium underlayer occurred after approximately 25 cycles.

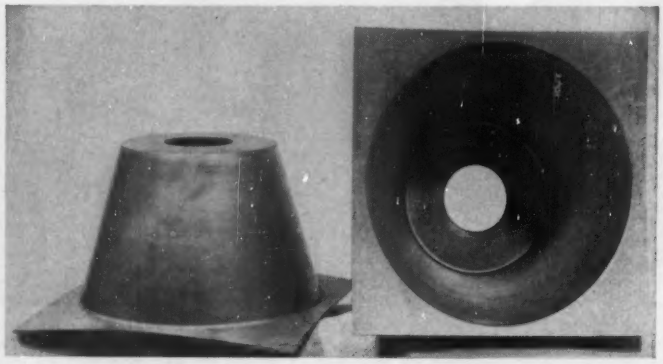

Fig. 5—Cones Floturned from 0.058-in. thick unalloyed molybdenum sheet at approximately 800 to 1100 F.

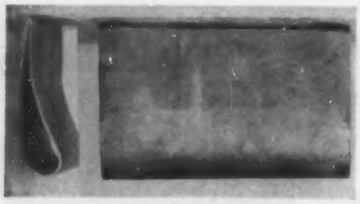

Fig. 6 — Gas-turbine guide vane made from 0.040-in. thick molybdenum, warm stretch-formed and brazed with AMS 4775 alloy in a hydrogen atmosphere.

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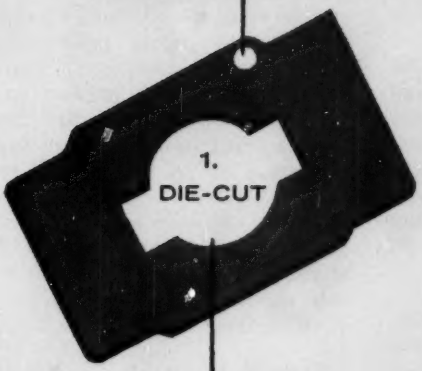

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MANUFACTURERS AND CUTTERS OF WOOL FELT

Organizing personnel for

Computer Operation

By E. R. Moore

Manager of Engineering
Detroit Edison Co.
Detroit

MACHINE computation, as discussed here, is an entirely different activity from others commonly encountered in engineering organizations. Furthermore, it is not one that can be considered as a part-time activity of an established organization, particularly since such engineering groups are already loaded down with their regularly assigned duties. For effective functioning, this new effort requires a group, properly constituted, for which this will become and remain an exclusive and full-time activity.

The process of solving engineering problems is radically different in the preparatory stages from that for business problems, and development of new procedures is required. Considerable specialized training of personnel is necessary before appreciable work production may be expected. As experience and literature accumulate, of course, need for pioneering in the many areas of application will naturally decrease, but this goal is still a long way off. This eventuality must be kept in mind, however, in deciding upon the size of group to establish.

Methods of Organization: Three distinctly different methods of organization may be conceived. The first of these is to set up one computing center to handle all computing work for the company. This includes the preparatory functions of planning and programming, as well as the actual machine operation. In this type of organization, the computer center handles both the business or data-processing type of problem, and the engineering or computation type.

A second method is for each department, or functionally related group of departments, to set up its own computing organization, complete with computing equipment.

The third arrangement is to have a centralized group responsible for the operation and maintenance of the machines, and to establish separate groups to handle the planning and programming of problems of data-processing and engineering natures.

One important determining factor in making the choice between the foregoing methods is the amount of applicable work in each area, since one of these machines requires a considerable work load for economical operation. The type of work in each area and available personnel are other important factors. In general, a different type of individual in background training and experience is required to handle engineering problems than is needed for so-called business problems.

Work-Production Methods: Associated with the selection of the type of organization to be established is the question of how actual work production is to be accomplished. There are several separate functions to be performed between the problem origination and its solution. These separate functions or operations are in series and cannot be performed simultaneously. This will have a bearing, as related to the volume of work, in determining the size and personnel distribution of the work group to be established.

First, it must be established that there is a problem which not only could but should be solved on these machines. Then follow the preparation stages, variously referred to as planning, programming or coding. Ultimate efficiency is attained not by the simple development of a method, but rather by the determination of the best method, and one that is compatible with the particular type of machine being used. Finally, the problem must be put through the machine and the results presented in understandable form.

One method of handling such work is to have each individual in the group carry a specific problem through all these stages from origin to final solution. The other method is to separate the work on a functional basis, and assign each function on all problems to the same individual. There is much to be said for each approach, and each company must make its own choice after a thorough analysis of local conditions.

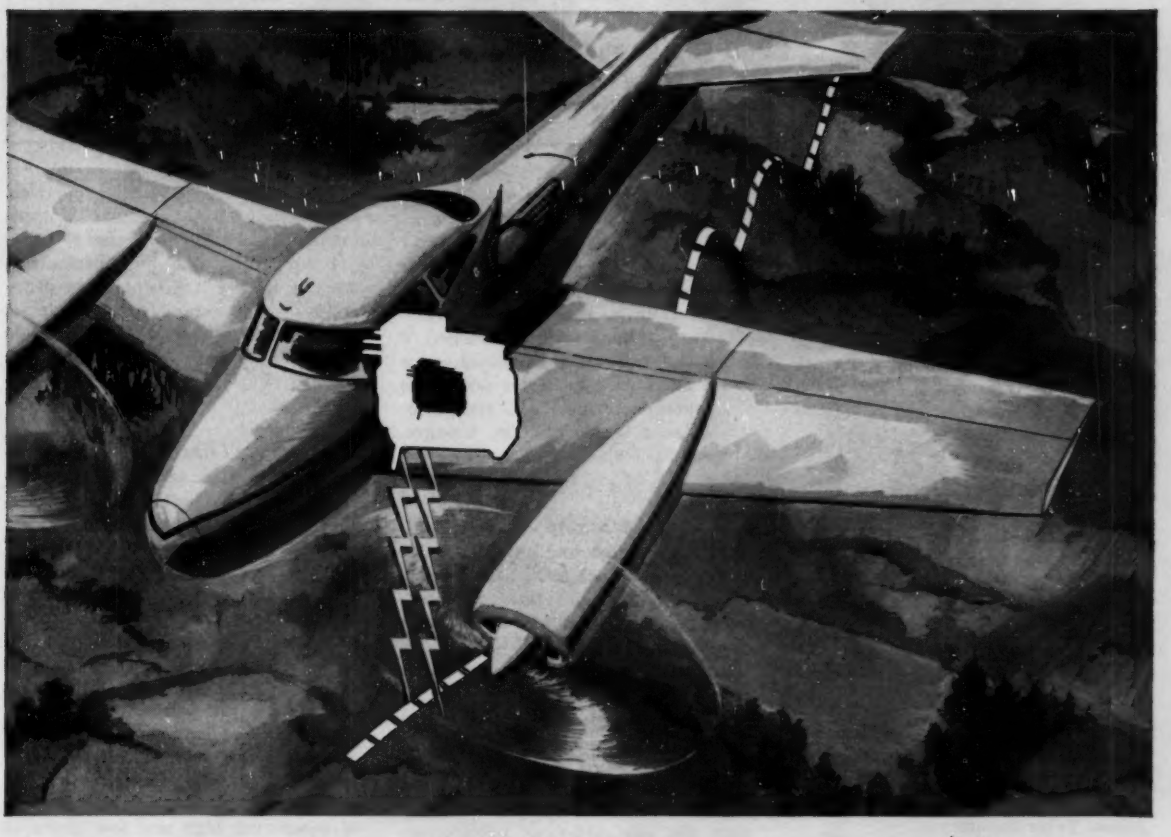
In most cases, members of the present engineering organization, with a relatively minor amount of additional training, are competent to perform the first function of problem origination. This consists of presenting the problem in terms of the conventional mathematical expressions familiar to engineers. The preparation and operating functions, however, are new and will usually require the developing of an organization to handle them. Since these functions are of such a specialized character, and the art is so fluid at the present time, these individuals should be working continuously in these areas.

Type of Personnel: A special type of individual is needed for this work, and some helpful testing procedures are available for their selection. Qualities such as imagination, an inquisitive mind, tenacity, a knack for trouble-shooting, self-confidence, and a determination to keep going despite repeated discouragement are necessary. In general, a college graduate is required. Mathematicians, business graduates, scientists and engineers have all been used.

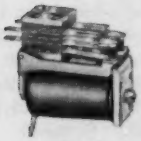
In engineering problems, the knowledge of both mathematics and engineering is required. Knowledge gained through experience with the company's engineering problems is a valuable asset. Since all of this rarely resides in one person, it is usually necessary either to select a mathematician and teach him engineering, or to select an engineer and teach him additional mathematics.

From a paper entitled "Organization and Personnel" presented at the AIEE Fall General Meeting in Chicago, October, 1956.

Potter & Brumfield *engineering is in this picture*



Which P&B relay did Television Associates specify
FOR THEIR AIRBORNE COMPUTER?



MH Series

MB Series

MC Series

Surveys for pipe lines, electric transmission routes and microwave paths are now made from the air, by radar. Television Associates of Indiana, Inc. developed this speedy new technique—and the equipment—which provides clients with detailed profiles of the terrain to be crossed.

Part of the equipment, an intricate airborne computer, requires relays that are fast-acting, light weight, versatile. They must have high shock and vibration resistance and remain operative in temperatures ranging from —45° C to +85° C.

Modified MH relays by P&B were specified. These miniature relays meet all Television Associates' requirements and provide high reliability in a mighty small package. Challenging relay problems are solved daily at P&B. Twenty-five years of creative engineering are behind every P&B relay. Write today for our new catalog.

ENGINEERING DATA

SERIES: MH Miniature Telephone.

CONTACTS: Up to 18 springs, maximum 9 in each stack, forms A, B, C, D, E, X and Y. AC relays are limited to a maximum of 2 poles. Various contact material available.

VOLTAGE RANGE: DC-.05 to 110 V.—AC-6 to 230 V. 60 cycle.

COIL RESISTANCE: 22,000 ohms maximum.

TEMPERATURE RANGE: High temperature range (DC) —55° C. to +135° C.
Standard DC —55° C. to +85° C.
Standard AC —45° C. to +40° C.
Other temperature ranges available to specification.

TERMINALS: Standard pierced solder lug holes will take (2) No. 18 hook-up wires. Adaptable for printed circuits.

ENCLOSURES: Dust cover plus wide range of hermetically sealed covers and types of terminations.

DIMENSIONS: 1-9/16" L. x 25/32" W. x 1⅜" H. (4c Relay).

P&B RELAYS AVAILABLE AT MORE THAN 500 DISTRIBUTORS IN ALL PRINCIPAL CITIES

Potter & Brumfield, inc. PRINCETON, INDIANA

Subsidiary of AMERICAN MACHINE & FOUNDRY COMPANY • Manufacturing Divisions also in Franklin, Ky. and Laconia, N. H.

HELPFUL LITERATURE

for Design Executives

For copies of any literature listed, circle item Number on Yellow Card—page 19

Centralized Lubrication

Automatic and semiautomatic centralized lubrication systems for small machines are covered in bulletin 4C. Bearing requirements, oil discharge volume and frequency of lubrication are factors considered in selection of these cyclic and one-shot units. 24 pages. Bijur Lubricating Corp.

Circle 650 on page 19

Centrifugal Pumps

Custom-built, high-speed centrifugal pumps for handling clear liquids and fine slurries are subject of bulletin P-3b and insert P-3c. Capacities range to 600 gpm and heads to 160 ft. 6 pages total. Ampco Metal, Inc.

Circle 651 on page 19

Heat Exchanger

Standard dimensions of basic sizes of the fixed bundle heat exchanger are tabulated in form HT-1. Tubes in this exchanger are bonded to the baffles to eliminate vibration wear. 4 pages. Yates-American.

Circle 652 on page 19

Gaskets & Shims

System of color coding which permits instant selection of the proper gage of a gasket, shim, spacer or washer is shown in illustrated bulletin. Color-Plast plastic material is available custom cut, or in roll and sheet form. 4 pages. General Gasket, Inc.

Circle 653 on page 19

Marking Tools & Equipment

A complete line of marking tools and machines ranging from hand stamps to automatic equipment is described in bulletin No. 11, entitled "If It's Worth Making, It's Worth Marking." Marking machine applications are shown. 16 pages. Geo. T. Schmidt, Inc.

Circle 654 on page 19

Absorption Dynamometers

Direct absorption dynamometers or water brakes for speeds up to 25,000 rpm and faster are usable for testing turbines, gear boxes and other rotating equipment. Full details and engineering data on Hydra-Brake units are given in bulletin B-12. 4 pages. Industrial Engineering Co.

Circle 655 on page 19

T & T-Slot Bolts

Two to three times stronger than soft forged bolts, Jergens forged T and T-slot bolts have machined heads to fit all table slots. Sizes and types are available to meet JIC standards. Specs are given in bulletin. 4 pages. Jergens Tool Specialty Co.

Circle 656 on page 19

Shear Pin Sprockets

Detailed design and application information on stock Link-Belt sprockets with shear pin overload protection are given in bulletin 2749. Stock sizes, torque ratings, hub dimensions and other data are presented. 4 pages. Link-Belt Co.

Circle 657 on page 19

Small-Engine Starter

Electric pushbutton starting is feasible for small gasoline engines with the new 110-v or battery operated electric starter described in bulletin FM273A. Unit easily replaces conventional hand starters. 4 pages. Fairbanks, Morse & Co., Magneto Div.

Circle 658 on page 19

Servo Building Blocks

How Servomation building blocks cut project time and minimize testing and break-in is explained in "pop-up" folder. Building blocks, electro-mechanical assembly kits and servosystem analyzers are briefly described. 4 pages. Servo Corp. of America.

Circle 659 on page 19

Tube Fitting Adapters

Straight thread plugs and adapters, O-rings for straight thread tube fittings, and steel and brass pipe fittings are subject of catalog 4360. Sizes range to 2-in. ID. 12 pages. Parker Appliance Co., Tube & Hose Fittings Div.

Circle 660 on page 19

Permanent Magnets

"The Newest of the Alnicos, Alnico 5Cb" is title of bulletin DFM-3 which gives the physical properties, dimensional limitations and a typical demagnetization and energy product curve for this new permanent magnet material. Comparative properties of all standard Thomas & Skinner permanent magnet materials are tabulated. 4 pages. Thomas & Skinner, Inc.

Circle 661 on page 19

Self-Locking Clinch Nut

Flush-mounted self-locking Superclinch nuts are reported to give excellent service when installed in Fiberglas, steel, aluminum, copper and other metals. Dimensions and installation tools are shown in illustrated catalog. 8 pages. Kaynar Co., Kaylock Div.

Circle 662 on page 19

Thread Gaging Guide

"Class 3A Threads" is title of thread gaging guide which tells how to avoid accepting misfit threaded fasteners. It presents basic principle of measuring high and low limits of pitch diameter tolerances and gives tips on gaging techniques. 16 pages. Standard Pressed Steel Co.

Circle 663 on page 19

Vertical Pumps

Details of Verti-Line vertical pumps with capacities from 20 to 30,000 gpm at heads up to 600 psi are given in bulletin 1100. Sectional views, schematic drawings, and performance data are included. 12 pages. Layne & Bowler Pump Co.

Circle 664 on page 19

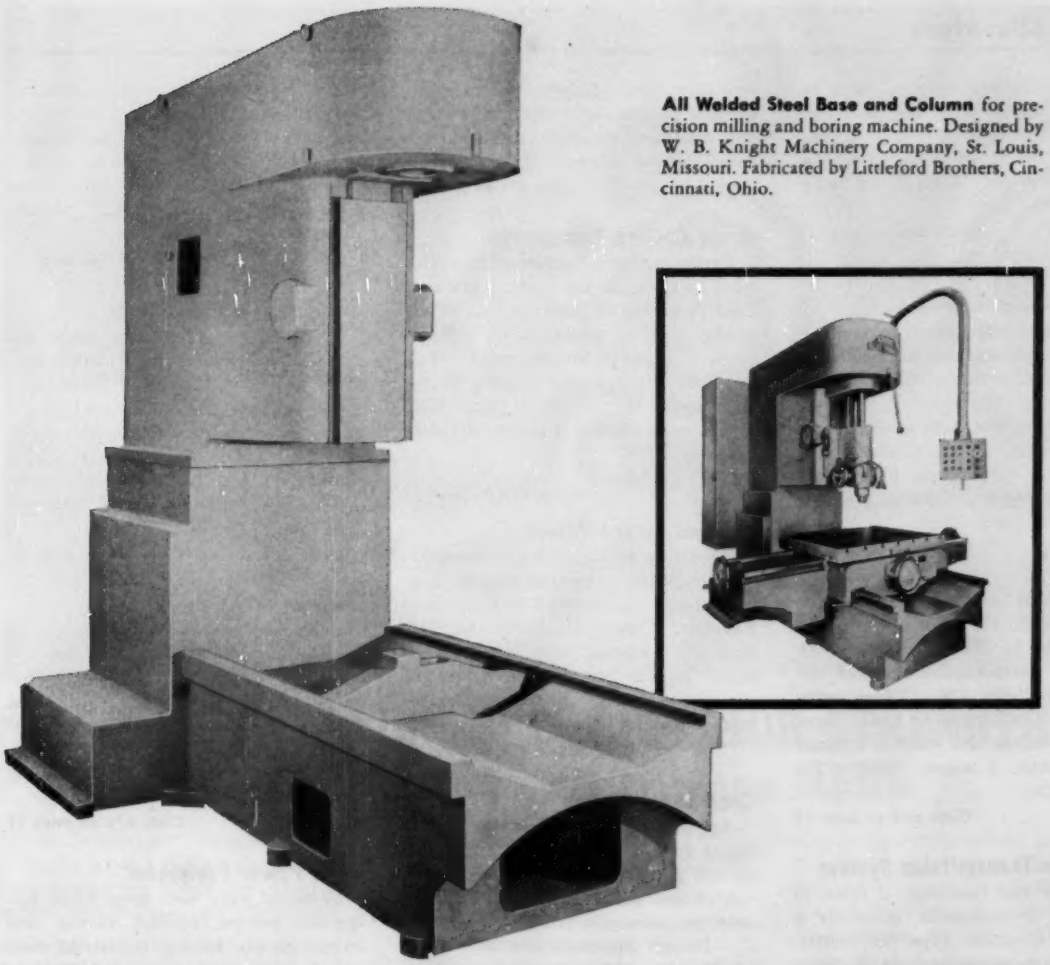
Strain Gages & Accessories

Flat grid, fine pitch, Bakelite strain gages are among the new products described in 1957 price list on SR-4 strain gages, instruments and accessories. Types are listed for wide range of testing purposes. 16 pages. Baldwin-Lima-Hamilton Corp., Electronics & Instrumentation Div.

Circle 665 on page 19

Rectilinear Recorder

Details of the new recti/riter rectilinear writing galvanometric recorder are contained in bulletin R-501. System changes curvilinear motion



All Welded Steel Base and Column for precision milling and boring machine. Designed by W. B. Knight Machinery Company, St. Louis, Missouri. Fabricated by Littleford Brothers, Cincinnati, Ohio.

MORE RIGID TO HOLD CLOSER ALIGNMENT

... Welded steel design makes it possible at lower cost

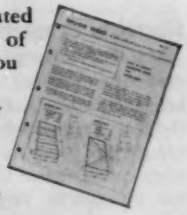
BY proper use of welded steel construction, many types of machines can be built to hold closer alignment and maintain higher tolerances. This is possible because steel is 2½ times as rigid as iron.

Because steel designs use less material, and because steel costs only a third as much per pound as iron, costs can be lowered substantially.

On these precision machines, rigidity for close alignment is combined with modern appearance. Additional savings in cost are possible since patterns and castings are eliminated.

Benefits like these could be duplicated in your designs. Lincoln's 45 years of cost-cutting experience can show you how.

Designers and engineers write for bulletins on designing for steel.



THE LINCOLN ELECTRIC COMPANY

Dept. 1119, Cleveland 17, Ohio

When steel is three times stronger than iron

Has 2½ times the rigidity

Yet costs ⅓ as much

WHY aren't all your products designed for welded steel

to true rectilinear motion, thus inscribing a signal that can be measured directly with a ruler. Accessories are described in supplemental bulletins. 8 pages. Houston Technical Laboratories.

Circle 666 on page 19

Electronic Wire

Designed for internal wiring of electrical and electronic equipment, meters and panels, line of high temperature electronic wire meets requirements of specification MIL-W-16878B. Complete data are given on this wire with thermoplastic, nylon and silicone insulations in bulletin 19-586. 4 pages. General Electric Co., Wire & Cable Dept.

Circle 667 on page 19

Temperature Control

Temperature ranges up to 1000° F are covered by line of model L-1S adjustable temperature controls detailed in bulletin 106. These units can be used in liquids or gases, have 15-amp switches and various contact arrangements. 2 pages. Burling Instrument Co.

Circle 668 on page 19

Pneumatic Transmission System

Just how the Laminair, a form of pneumatic transmission, provides a sensitive, accurate type of instrumentation is explained in bulletin 750. Mechanism produces an output air pressure that varies directly with flow through a venturi tube, nozzle or orifice plate, and which can be transferred and used to operate a remote receiving instrument. 8 pages. Simplex Valve & Meter Co.

Circle 669 on page 19

Electrical Contacts

Materials, properties, forms and uses of electrical contact materials are tabulated in short-form catalog C-522. Application and design data are given on silver, palladium, nickel, alloy and powder metal compositions for practically any contact use. 4 pages. Gibson Electric Co.

Circle 670 on page 19

Mercury Switch Controls

Automatic controls for heating, ventilating, air conditioning and industrial use are subject of catalog 857. Controls use sealed mercury switches for wearproof, silent, long-life operation. Types are described for pressure, temperature, differential, limit, liquid level and other control functions. Relays, thermostats, damper motors, and tilting and magnet operated mercury switches are detailed. 56 pages. Mercoid Corp.

Circle 671 on page 19

Resin Casting Compounds

Techniques involved in using epoxy resin compounds for casting are covered in technical bulletin 10. It explains how to make molds or patterns, vacuum forming molds, dies, jigs and fixtures, and potting or encapsulation of electrical and electronic components. 4 pages. Smooth-On Mfg. Co.

Circle 672 on page 19

Tubular Screen Filters

Operation of Filter-Matic automatic, self-cleaning, tubular screen, vacuum filters is described in illustrated bulletin. Capacities are 5 to 1000 gpm for coolants, oils, solvents and other liquids requiring removal of minute particles. 4 pages. Industrial Filtration Co.

Circle 673 on page 19

Centrifugal Pumps

Applicable for general service at heads to 275 ft and with capacities to 600 gpm, type GSC close-coupled centrifugal pumps will handle liquids with temperatures from —40 to 250° F. Design specifications are given in circular 191. 4 pages. Dean Brothers Pumps Inc.

Circle 674 on page 19

V-Belts

Handbook of V-belt drive design and selection contains wealth of data on various drive types, how to design them, basic related data, installation, maintenance and many selection and specification tables. An application chart is also included. 180 pages. Dayton Rubber Co.

Circle 675 on page 19

Packaging with Plastics

"1957 Guide to Improved Packaging" shows applications of plastic films, adhesives, coatings, laminations, sheets and molded and extruded products to package practically any product. Technical information service is explained. 12 pages. Bakelite Co.

Circle 676 on page 19

Airborne Equipment Switches

"Basic Switches for Airborne Equipment" is title of catalog 78 on phenolic encased aircraft switches and metal-covered, hermetically-sealed and high - temperature switches. Over 140 switches, actuators and terminal enclosures are described. 32 pages. Minneapolis-Honeywell Regulator Co., Micro Switch Div.

Circle 677 on page 19

Stainless Steel Fasteners

"AN" is title of catalog which describes government specification aircraft bolts, slotted and Phillips machine screws, flat and round rivets and washers made of stainless steel. Pictures, stock sizes and principal dimensions are given for each item. 12 pages. Allmetal Screw Products Co.

Circle 678 on page 19

Teflon-Lined Pipe

Second of a series on Teflon equipment, bulletin T-100 details the application of Teflon as a liner for schedule 80 steel pipe. Pipe lined with Teflon will withstand up to 350° F and solves tough corrosion problems in processing. 2 pages. Haveg Industries, Inc., Halocarbon Div.

Circle 679 on page 19

Fluid Power Equipment

Hydreco gear and Dual-Vane hydraulic pumps, control valves and cylinders are among industrial fluid power equipment presented in condensed bulletin 400. Uses include earth moving and materials handling equipment and farm machinery. 8 pages. New York Air Brake Co., Kalamazoo Div.

Circle 680 on page 19

Temperature Chart

Easy-to-read tables of Fahrenheit and Centigrade temperature equivalents are found in this temperature conversion chart. Pocket size chart covers range from —40 to 298°, either scale, and their equivalents. Moeller Instrument Co.

Circle 681 on page 19

Hydraulic Hose Fittings

Catalog 4433 covers reusable Hozelok fittings for high pressure rubber-covered double wire braid hose. Sizes range from 3/16 through 2 in. ID. 4 pages. Parker Appliance Co., Tube & Hose Fittings Div.

Circle 682 on page 19

Terminals & Splices

Two bulletins respectively describe Fingrip strip terminals for use on

SIMPLIFY DESIGN, GAIN SUPERIOR STRENGTH!

Specify Hunter Douglas Aluminum Impacts

Hunter Douglas Aluminum Impacts are solving a lot of important design problems in all types of industry. Here are quick answers to everyday questions.

HOW DO IMPACTS DIFFER FROM COLD FORGINGS? Basically, only in material used. "IMPACT EXTRUSIONS" are thin walled components extruded from 2S or *soft material.* "COLD FORGINGS" are thick walled shapes made from *heat treatable* aluminum alloys. For simplicity, we'll consider both synonymously.

HIGH STRENGTH—You will find all the properties of forged structures in impacts—exceedingly dense, fine grain, strength and toughness with unusual freedom from porosity and internal flaws...a natural for *high pressure applications,* either gas or liquid. In impact extrusions, flow lines actually follow part contours, adding extra strength. Often strength is satisfactory as extruded, without subsequent heat treatment. Our new alloy, HDX, gives tensiles as high as 85,000 psi with minimum yield strength of 80,000 psi for highly stressed applications.

GREATER SIMPLICITY—Complicated multiple piece assemblies can often be replaced with a single impact. An integral impact eliminates mechanical and/or welded joints and results in a smooth surface, unbroken by seams.

MORE DESIGN FLEXIBILITY—Generally, we can put extra metal where it's needed or thin up sections where required... like making bottoms of cans thicker than walls, adding integrally forged cavities or bosses of any shape, internal or external. Fluted or ribbed sidewalls, either decorative or functional, are easily produced by impact extrusions.

TOLERANCES—Hunter Douglas shines on accuracy...holds tolerances as close as ±.005" on specific diameters and matches screw machine tolerances on wall thicknesses.

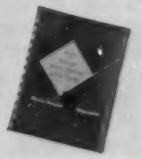
ZERO DRAFT—If you want straight, uniformly thick sidewalls, Hunter Douglas Impacts are for you. Zero draft cuts all unnecessary machining and reduces metal waste. Impacts usually require only trimming, drilling, tapping or minor clean-up.

SMOOTH, BRIGHT SURFACES—There's no scale or rust and surfaces range up to 125 microinches, as extruded...plenty smooth for lithographing or painting without secondary finishing. Real dazzlers result by polishing, satin finishing or anodizing. For extra wear or corrosion resistance anodizing is the answer.

UNLIMITED PART GEOMETRY—We've made impacts round, square, rectangular, triangular, octagonal and most other shapes. We do best if parts are symmetrical along the center axis, but good tooling often solves even a tough design problem. A sketch will enable us to advise or suggest means to an end.

WHERE TO USE IMPACTS—Here are rule-of-thumb considerations: hollow parts with one closed end; walls or surfaces of zero draft; lengths of 8 to 8 times O.D.; strength of hammered or pressed forgings; integral ribs, bosses or webs; tolerances of ±.005"; typical surface finishes of 125 microinches; concentric, multiple diameters.

WE'D LIKE TO HELP—
Our booklet gives valuable impact and cold forging information and our engineers are eager to advise. Simply write on your letterhead we'll do the rest.



Hunter Douglas Aluminum Corporation

HUNTER DOUGLAS ALUMINUM CORPORATION • DEPT. MD-2, RIVERSIDE, CALIFORNIA • TELEPHONE OVerland 3-3030

stoves, switches, fans, timers, capacitors, appliances and auto harnesses; and Sealink water-sealed cable-junction splices. 4 pages each. Burndy Corp.

Circle 683 on page 19

Analog Computers

Booklet "High-Speed Analog Computers, Key to Rapid System Development" defines in question-and-answer style certain types of computers and summarizes applications of each. Comparisons between analog computation and fields of photography and genetics are included. 8 pages. GPS Instrument Co.

Circle 684 on page 19

Balancing Machines

Electronic industrial balancing machines for kinetic and dynamic balancing of all rotating machine parts are subject of form 24-1. Specifications are given for machines with diametral ranges of ½ to 44 in. and 1 to 68 in. 16 pages. Stewart-Warner Corp.

Circle 685 on page 19

Ceiling Lighting

Detailed information on Wakefield luminous ceilings, modular lighting equipment, pendant mounted fixtures and the high frequency lighting system is provided in booklet AIA 31 F. Last system operates at 400 or 600 v at 840 cycles. 12 pages. Wakefield Co.

Circle 686 on page 19

Oil-Tight Pushbuttons

Added to line of oil-tight pushbuttons are the Roto-Push single button selector and the Pres-Test indicating light. Units are described in bulletin EL-178 along with other units utilizing a neoprene diaphragm seal. 26 pages. Cutler-Hammer, Inc.

Circle 687 on page 19

Molded Rubber Products

Photos and descriptive information on typical extra-large, hard rubber products which may be compression or transfer molded on versatile 400 and 600-ton presses are given in brochure E-422-56. 4 pages. Electric Storage Battery Co., Stokes Molded Products Div.

Circle 688 on page 19

Ceramics

Descriptive and engineering data on commercial white porcelain, Nu-Blac, Thermolain, steatite, Vitrolain, Humidolain, Lavolain and 5606 refractory ceramic materials are contained in illustrated catalog 57. Mechanical, electrical and physical properties are given. 20 pages. Star Porcelain Co.

Circle 689 on page 19

Switches

Line of pushbutton, lever and turn switches is illustrated, and their ratings, dimensions and other specifications given in catalog 200. 4 pages. Donald P. Mossman, Inc.

Circle 690 on page 19

Autotransformers

Specifications, prices, dimension drawings and photographs of Variac single and ganged adjustable autotransformers are found in bulletin 0. Output voltages are from 0 to 117 per cent of line voltage. 24 pages. General Radio Co.

Circle 691 on page 19

Infrared Weapons Systems

Applications and research on infrared weapons systems is discussed in booklet IR-9902-56. Various military applications are covered, along with infrared control systems for industry. 8 pages. Servo Corp. of America.

Circle 692 on page 19

Electrical Insulation

Glastic Grade TS polyester glass-mat laminate, subject of illustrated property sheet, combines good physical properties with high electrical properties and heat resistance. Listed are 28 properties. It is made in thicknesses to 1¼ in., strength to 18,000 psi. Glastic Corp.

Circle 693 on page 19

Variable Pitch Drives

Single groove wide range variable pitch and companion sheaves for R and W belts and locking ring type variable pitch sheaves for Q and R wide range belts are described in illustrated catalog V-183-A. Specifications of these units, and variable pitch locking ring sheaves, are given. 12 pages. Browning Mfg. Co.

Circle 694 on page 19

Seamless Tubing

Use of Croloy 25-20 alloy seamless tubing for elevated temperature or corrosive service use is covered in bulletin 286M. Its properties, chemical composition, structural stability, corrosion resistance, applications and prices are given. 4 pages. Babcock & Wilcox Co., Tubular Products Div.

Circle 695 on page 19

Nickel Cadmium Batteries

Practicability of Nicad miniature nickel and cadmium batteries for various applications is detailed in illustrated bulletin 501. Technical data on the sintered plate units are included. 8 pages. Nickel Cadmium Battery Corp.

Circle 696 on page 19

Pushbuttons

Extensive series of general purpose and oil-tight pushbuttons is described and illustrated in catalog 5606A. Specifications and prices are given and available accessories are detailed. 32 pages. Furnas Electric Co.

Circle 697 on page 19

Small Socket Screws

Microsized Unbrako socket screws for miniaturized electronic equipment and instruments are described in illustrated bulletin 2055. Tabular data on sizes from No. 0 to 3, in alloy or stainless steel, are included. 4 pages. Standard Pressed Steel Co.

Circle 698 on page 19

Data Handling System

High speed storage on magnetic tape, playback into electric typewriter or serial IBM summary punch and continuous time readout are features of No. 5780 data handling system. Illustrated bulletin describes its operation. 2 pages. Beckman Instruments, Inc., Berkeley Div.

Circle 699 on page 19

Limit Switches

Twenty-one contact arrangements for nine Loxswitch heavy duty machine tool limit switches are described in illustrated bulletin 956. Housings, wiring diagrams, ratings, operating data and electrical characteristics are covered. 8 pages. R. B. Denison Mfg. Co.

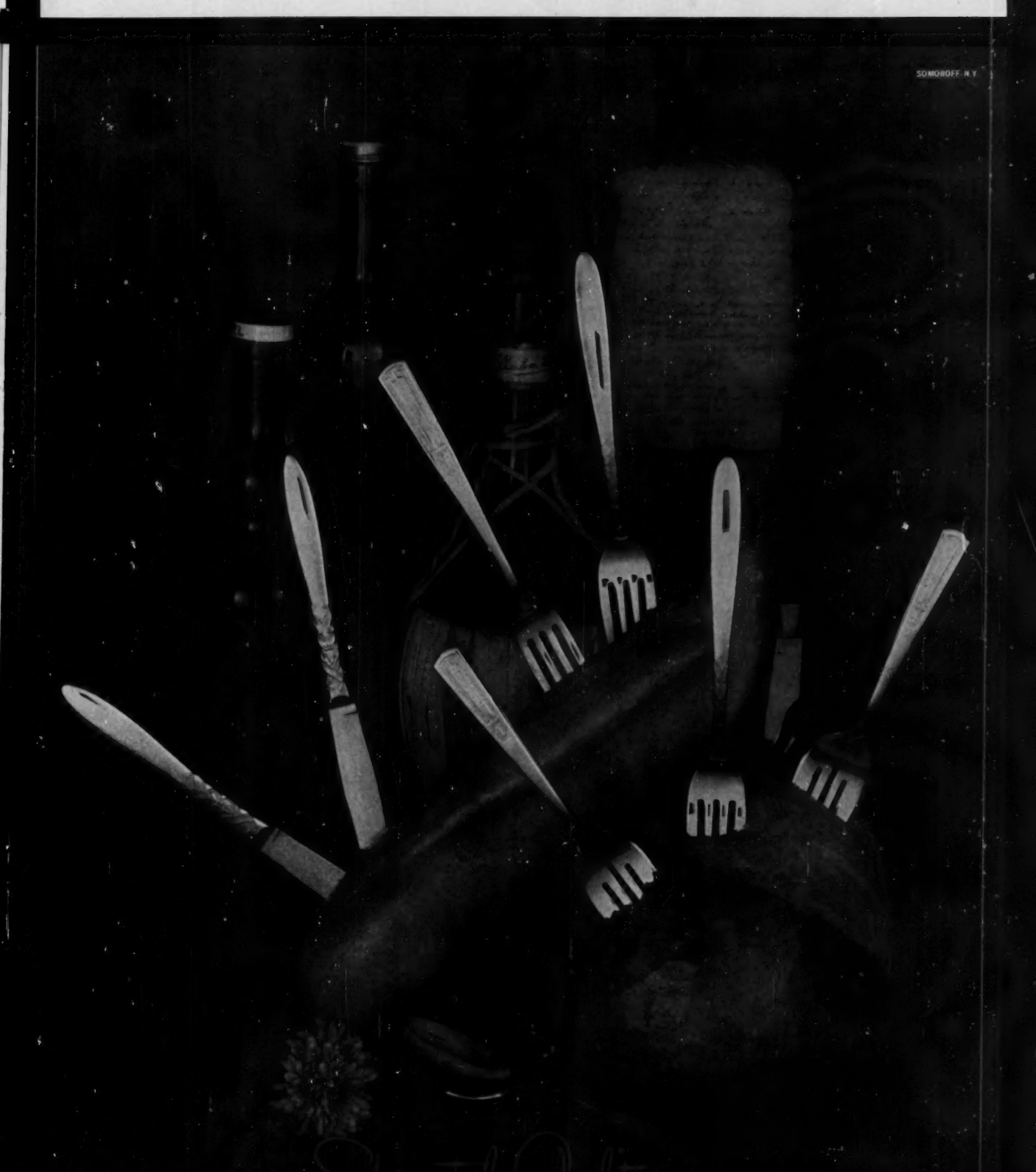
Circle 700 on page 19

Roll Neck Bearings

"SKF Multi-Row Cylindrical Roll Neck Bearings" is title of catalog 436 which contains engineering and technical data on this product, designed for all types of hot and cold rolling mills. Specifications and engineering drawings are included. 24 pages. SKF Industries, Inc.

Circle 701 on page 19

Circle 477 on page 19→



IN FLATWARE, TOO, Sharon Steel Quality STANDS OUT

A thorough knowledge of flatware manufacture — uncompromising adherence to analysis specifications — plus, the industry's finest finishes are reasons why so many of the nation's leading stainlessware makers demand Sharon Quality Stainless Steels.

SHARONSTEEL — *For 56 Years a Quality Name in Steel*

SHARON STEEL CORPORATION, SHARON, PENNA.

CHICAGO, CINCINNATI, CLEVELAND, DAYTON, DETROIT, GRAND RAPIDS, INDIANAPOLIS, LOS ANGELES, MILWAUKEE, NEW YORK, PHILADELPHIA, ROCHESTER, SAN FRANCISCO, SHARON, MONTREAL, TORONTO

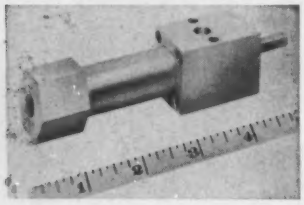
New Parts and Materials

Use Yellow Card, page 19, to obtain more information

Air Cylinders

miniature units have 5/8-in. bore size

Hydraulic and pneumatic cylinders with 5/8-in. bore are available in single and double acting models. Low-pressure rating is 150 psi air and 750 psi oil; high-pressure rating is 1500 psi oil. Three mounting styles are available: Universal (foot and/or flange), clevis and trunnion. The 5/8-in. size eliminates need for a reducing valve on ap-



plications where small force outputs are required. Low volumetric displacement makes possible the use of smaller pumps and valves. Cylinders provide reduced inertia for high speed applications. They have brass heads, brass or steel barrels, and honed, stainless-steel piston rods. **Airoyal Co.**, 1990 Springfield Ave., Maplewood, N. J.

Circle 702 on page 19

Wire Splice

is water-sealed and insulated

Sealink is composed of a tinned copper link, a transparent nylon insulation sleeve, and anodized aluminum sealing rings. Permanent, watersealed and insulated, it accommodates AN wire sizes No. 26 through No. 10 and is color-coded for easy size identification. Used as either a two-wire water-sealed

splice, or for multiwire applications, it meets military specifications. **Burndy Corp.**, Norwalk, Conn.

Circle 703 on page 19

Plexiglas Sheets

transparent or translucent in large sizes

Cast acrylic sheets are available in sizes to 8½ by 10 ft in both colorless transparent and translucent colors. Sheets provide a surface area up to 85 sq ft. Typical uses are in internally-illuminated signs, large area glazing, fluorescent luminaires, dome skylights and other architectural applications. Thicknesses of either 0.187 or 0.250-in. are available. **Rohm & Haas Co.**, Washington Square, Philadelphia 5, Pa.

Circle 704 on page 19

Way Cover

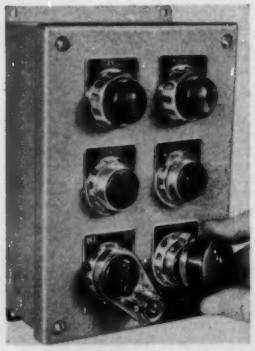
of extruded aluminum panels

Way-Life cover stops chips, grit or other foreign material from clogging or damaging machine ways or way mechanisms. It is designed principally for boring mills, planers, large grinders and vertical milling machines. Rigid construction permits the operator to walk on the cover while the machine is in operation, facilitating machine servicing and job set-up. Built of interlocking, 1½-in. wide extruded aluminum panels, the cover is custom-made to fit any width or length machine and will not burn, tear or dent. Panels roll up compactly and automatically at either end of the machine. **Futurmill Inc.**, 6360 Highland Rd., Pontiac, Mich.

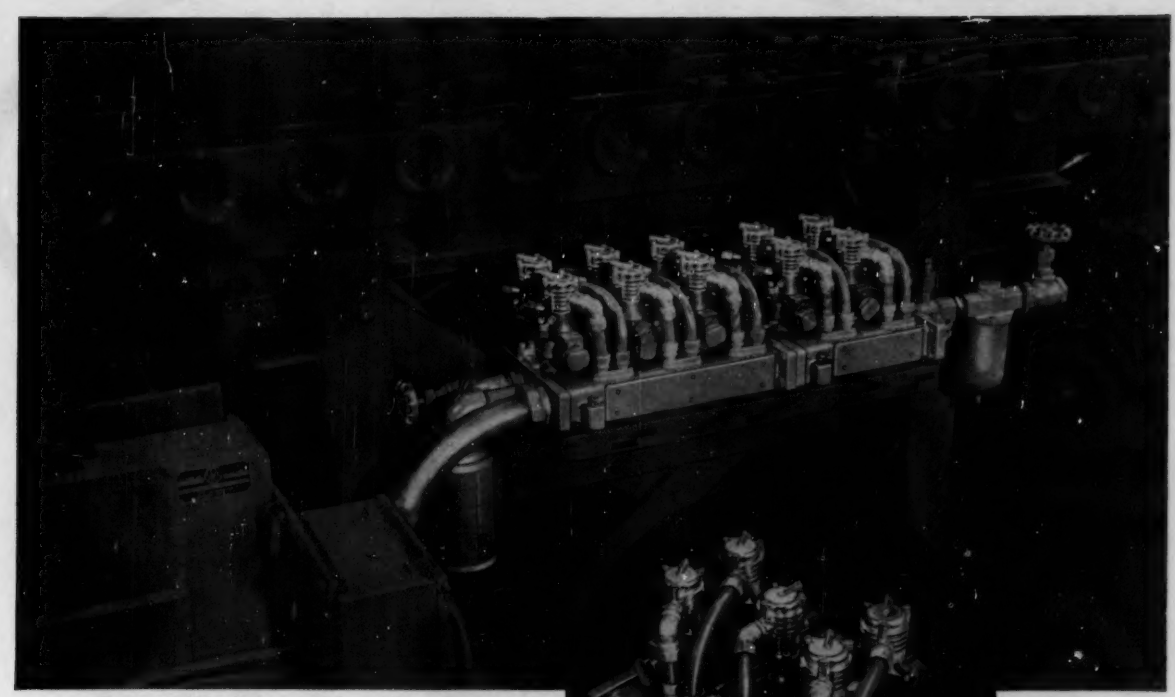
Circle 705 on page 19

Pushbuttons and Accessories

are rated to 550 v ac-dc



Heavy-duty Oil Tight pushbutton line includes pushbuttons, selector switches, selector pushbuttons, pilot lights and accessories such as mushroom head, lever and key lock. All units are built around one standard contact block. Blocks can be used singly or in tandem, mounted vertically or horizontally. Operator consists of a metal button or selector knob which is free to slide or rotate within a metal sleeve. Oil seal prevents oil from entering the enclosure and switching mechanism. Accessories can be



This bank of manifold-mounted Speed King valves controls a foundry mold flask indexing unit custom-built by Spo, Inc., Cleveland, for a major automotive manufacturer.

to simplify piping and wiring of complex control valve installations, use...

VALVAIR'S NEW SPEED KING MANIFOLDS

Cut material and assembly labor costs on multiple control valve installations . . . use Valvair's new 2 and 3-station manifolds! Common inlet, exhaust and wiring passages, plus equally-spaced cylinder ports, eliminate unnecessary piping and wiring . . . keep installations neat. Cast aluminum manifolds may be ganged for installation of any number of valves. O-rings assure leak-free connections.

Easier in-use service is another benefit! Individual pilots, valves or entire manifolds are replaceable as units to minimize machine downtime.

And, Speed King manifolds *are available for immediate delivery from stock.* Before you engineer new equipment or up-grade machines now in service, investigate the design and cost advantages of Valvair Speed King manifolds. Valvair Corporation, 454 Morgan Ave., Akron 11, Ohio.

AA-4967

Ganged 3 station Speed King manifolds provide neat piping . . . simplify construction and maintenance of this master control console which operates a battery of Spo, Inc. automated foundry equipment.

PIPING	—1 in. NPT intake and exhaust ports, common to all stations. Pipe threads, both ends, and O-ring grooves.
PORTING	—Optional ⅜ or ½ in. NPT cylinder ports. Side and bottom outlets, flush pipe plugs.
WIRING	—1¼ in. conduit passage, with side access cover, common to all stations. Pipe threads, both ends, and O-ring grooves. Pilot leads encased in flexible conduit.
VALVES	—2 or 3 stations for single and double solenoid Speed King valves. 2, 3 and 4-way; remote-operated; speed controlled; and power-centered neutral valves may be used in any number and combination.
MOUNTING	—2 mounting legs per manifold. Kits of O-rings and through bolts, for ganging, also available.

Find your nearest representative in the 'Yellow Pages'

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Valvair

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. . . CONE-DRIVE gearing has no equal.

You can drive the most delicate equipment or the heaviest industrial machinery without vibration or noise through a set of Cone-Drive gears.

Smooth delivery of power is an outstanding feature of Cone-Drive double-enveloping worm gearing. It's the result of a unique design that puts one-eighth of all gear teeth in simultaneous, full-depth contact with the worm threads.

The contact between teeth is "area" rather than the line or point type contact found in cylindrical worm gearing. This distributes the load over more area on each tooth to boost load-carrying capacity.

Want smooth, chatter-free, efficient power in a compact package? Cone-Drive gears will give it to you in gearsets or speed reducers in a wide range of models and sizes.

Ask for Bulletin 600-C for details.

CONE-DRIVE GEARS
Division, Michigan Tool Company

DOUBLE ENVELOPING GEAR SETS & SPEED REDUCERS
7171 E. McNICHOLS ROAD • DETROIT 12, MICHIGAN

Circle 479 on page 19

shifted easily from one button to another without interrupting operation of the panel. Oil-tight pilot lights are built for direct voltage, transformer or neon application. Extended shatter-resistant lenses provide greatest angle of visibilty. Pushbuttons are rated to 550 v ac-dc. **Furnas Electric Co.**, 1045 W. McKee St., Batavia, Ill.

Circle 706 on page 19

Setscrews

for miniaturized equipment

Mini-Mite No. 0, 1, 2 and 3 setscrews in socket, socket cap and slotted styles, and in a variety of

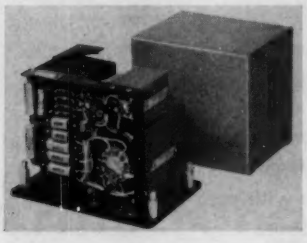
points, are for use in servomechanisms, electronic equipment and other miniaturized units. The screws have fully formed fine threads, uniformity for maximum contact with driving tools, and special heat treating to give high tensile strength without brittleness or decarburization. They give maximum reduction in weight and bulk without sacrificing holding power. **Set Screw & Mfg. Co.**, Bartlett, Ill.

Circle 707 on page 19

Servo Amplifiers

for servo motor control in automatic control loops

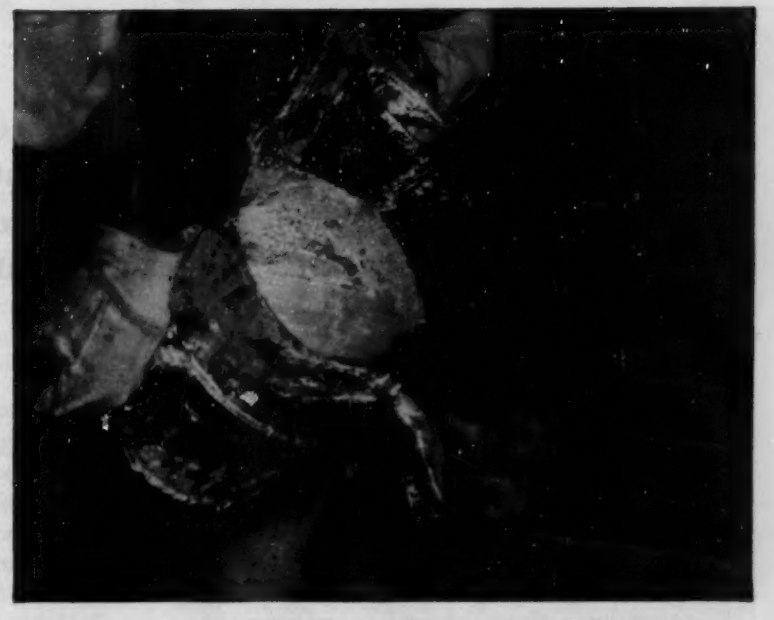
Line of servo amplifiers for both 60 and 400 cps servo motors range



in shaft power from 1 to 50 watts. Units have universal characteris-

(*Continued on Page* 160)

Do you hear meaningless claims when you buy self-aging Aluminum Alloys?



Federated Tenzaloy is the most widely used of all high-strength, self-aging aluminum alloys because it has the highest yield strength, and it has the best all-around combination of properties. Yield strength is the true measure of a metal's ability to take punishment, regardless of other claims that are made.

When you buy Federated Tenzaloy, you can be sure it will perform as well as its specifications indicate. Tenzaloy is produced under the supervision of ASARCO's Central Research Laboratory, where refining and testing techniques control impurities to parts per million, if required.

Hundreds of foundries and manufacturers use Tenzaloy where heat treating is impractical because of casting design or size. Hundreds more cast Tenzaloy because heat treating facilities are not available.

Why not ask your Federated field man to tell you who uses this metal and how? He will be around to see you soon, and it will benefit you to talk to him.

Federated Metals ASARCO

Division of

AMERICAN SMELTING AND REFINING COMPANY

120 BROADWAY, NEW YORK 5, N. Y.

Circle 480 on page 19

New Accopac materials useful range of

Expanded fiber sheet gasket line now includes radically different asbestos materials – offers high sealing efficiency at flange pressures of 10,000 psi or more and temperatures to 500° F.

The new, expanded line of Accopac® materials brings an entirely new degree of sealing efficiency to fiber sheet packings. Where plant fiber gaskets are called for, Accopac offers dimensional stability and improved dependability. For applications where compressed asbestos materials are now specified, the new, flexible Accopac asbestos compositions offer easier handling and lower cost along with excellent sealing characteristics.

For flange pressures from 800 – 2,000 psi

Applications in this range of flange pressures usually require gaskets with relatively high compressibility. To meet this need, Accopac materials made of cellulose fiber, ground cork, and synthetic rubber binders are available. These materials need relatively light bolt pressures to seal normal joints. They conform to the surface irregularities commonly found in lightweight stampings and castings. These Accopac materials are recommended where temperatures do not exceed 250° F. Materials in this class are designated as CS-301 and CN-705.

For flange pressures over 2,000 psi

For heavy-duty flanges where bolt pressures are 2,000 psi or higher, there are Accopac materials that contain no cork. These are dense formulations designed to take heavy loads with minimum loss of bolt torque. Where temperatures do not exceed 250° F., they offer an economical replacement for compressed asbestos sheet packing. Compositions included in this group are N-820, N-852, N-854, and D-856.

For high-temperature applications

For sealing jobs where flange temperatures are up to 500° F. and internal pressures are up to 500 psi, a group of new asbestos-fiber Accopac materials is available. These materials are unique among asbestos gasket materials. They're tough, flexible, and easy to handle. They die-cut cleanly, and there are no loose fibers to become detached and contaminate contained fluids or clog orifices.

Accopac asbestos compositions AS-428 and AN-859 seal at flange pressures of 2,000 psi, somewhat lower than the pressure required for the general run compressed asbestos sheets. Although Accopac asbestos materials are more compressible than conventional sheet materials, they maintain the desired bolt torque.

All Accopac materials are available in rolls, sheets, ribbons, or die-cut pieces. For more information, get in touch with your Armstrong representative. Or write direct.

(Advertisement)

greatly extend fiber sheet gaskets

WHY ACCOPAC MATERIALS SEAL EFFICIENTLY

All Accopac materials are made by a patented modification of the beater saturation process in which individual fibers are coated with a synthetic latex binder before the sheet is formed.

This process assures uniform distribution of fibers and binder. The result is a strong, homogeneous sheet. Even in very thin gauges, Accopac materials are tough and flexible.

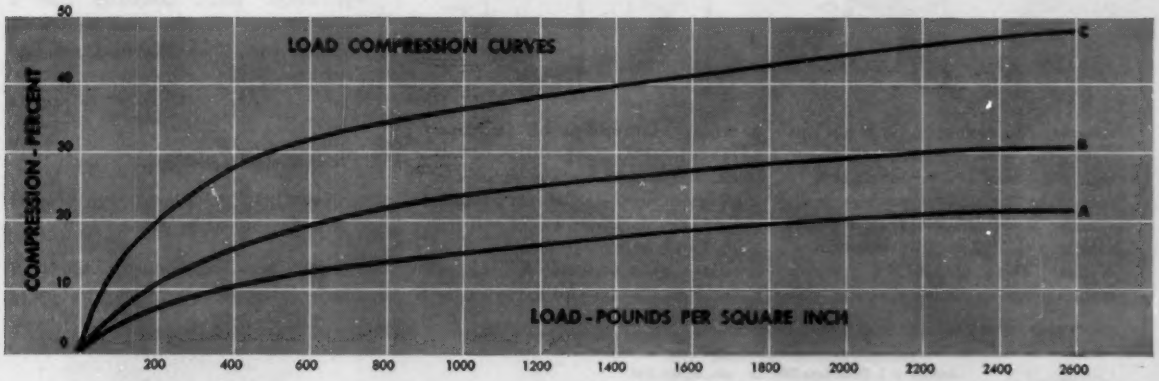
The synthetic latex binder in Accopac compounds is non-volatile and non-extractable. It cannot be leached out by the action of contained fluids or be vaporized by heat, as often happens with conventional glue-glycerine sheets. Even in alternately wet-and-dry applications, the Accopac binder-fiber structure remains intact.

To provide resistance against a wide variety of oils, solvents, chemicals, and gases, the Accopac line offers a choice of synthetic latex binders. For example, for certain oil and all water services, the styrene-type (Buna S) binder is usually recommended; for oil, gasoline, and other aromatic fuels, the nitrile-type (Buna N) binder is generally suitable, although the chloroprene-type (neoprene) is preferred by some.

Accopac Cellulose-and-Asbestos Fiber Gasket Materials

Type	Composition	Curve	Tensile Strength (Minimum) AMD	Percent Compressibility* (1000 psi)
CS-301	cellulose fiber, cork, and synthetic rubber (styrene type)	C	800	30-45
CN-705	cellulose fiber, cork, and synthetic rubber (nitrile type)	C	1000	30-45
N-820	cellulose fiber and nitrile-type rubber	A	3000	10-20
N-852	cellulose fiber and blend of synthetic rubber	B	1800	17-27
N-854	cellulose fiber, mineral filler and nitrile-type rubber	B	2500	15-25
D-856	cellulose fiber and chloroprene-type rubber	B	2000	17-27
AS-428	asbestos, styrene-type synthetic rubber	B	1200	17-27 (1000 psi) 30-40 (5000 psi)
AD-838	asbestos chloroprene-type synthetic rubber	B	1200	
AN-859	asbestos nitrile-type synthetic rubber	B	1700	

*Tested per ASTM D-1147-53T



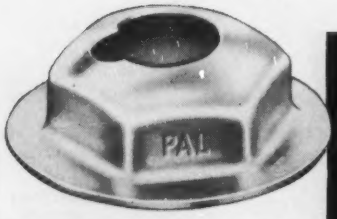
Armstrong ACCOPAC

. . . used wherever performance counts

You'll find more helpful information on the whole line of Accopac fiber sheet gasket materials in this new folder. Write for your copy today. Address Armstrong Cork Company, Industrial Division, 7002 Dean St., Lancaster, Pa.

How a TV Accessory Manufacturer

SAVES — 45% on Parts Cost — 50% on Assembly Cost with



WASHER TYPE
PALNUT
TRADE MARK ®
LOCK NUTS

	Parts	Pieces per Unit	Cost per M	Parts Cost per M Units	Assembly Cost per M Units
OLD WAY— 3 PARTS	Hex nuts	12	$2.17	$26.04	
	Flat Washers	12	.60	7.20	
	Lock Washers	12	.50	6.00	
				$39.24	$57.00
PALNUT WAY— 1 PART	PALNUT Washer Type	12	$1.80	21.60	28.50
			Savings	$17.64	$28.50

TOTAL SAVINGS PER M UNITS—$46.14

Use 1 part | instead of this | or this | or this

Whether you now use a plain hex nut alone—or with a lock washer—or with a flat washer—or all three . . . you make substantial savings with Washer Type PALNUTS, in parts, handling and assembly operations. Washer Type PALNUTS have a resilient spring locking action that provides vibration-proof fastening of sheet metal assemblies, components, parts and other moderate-load assemblies—are safer for fragile parts. They assemble easily and fast with hand or power drivers. Send details of your assembly for suggestions, free samples and literature.

THE PALNUT COMPANY, 75 Glen Road, Mountainside, N. J.
Subsidiary of United-Carr Fastener Corp.
Canada: P. L. Robertson Mfg. Co., Inc., Milton, Ont.

Many types available:
- Wide range of screw sizes
- Variety of base diameters
- Sealer Washer Type
- Spacer Washer Type
- Grounding Washer Type
- Electrical Washer Type

Circle 482 on page 19

New Parts

(*Continued from Page* 157)

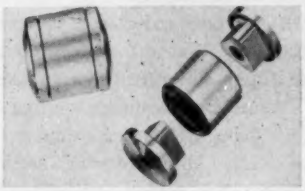
tics and flexible input circuits. Circuit techniques range from vacuum tube to transistor-magnetic. Packaging styles include hermetic sealing, plug-in, and quick disconnect. Input networks are arranged for single-speed synchro and pot data, two-speed synchro data, or dc data. **Industrial Control Co.,** Wyandanch, N. Y.

Circle 708 on page 19

Flexible Couplings

for fractional horsepower use

Three new couplings provide bore sizes from 3/16 to 1¼ in., diameters from ⅞ to 2½ in., and lengths from ⅞ to 2¼ in. Designed primarily for fractional-horsepower duty, the couplings consist of two durable, lightweight aluminum hubs which fit into synthetic rubber molded into an aluminum center ring. They are easily installed and lined up, and need no lubrication. Shock-absorbing properties of the synthetic rubber compensate for normal misalignment during operation. Each coupling has a replaceable center ring. **Smith & Serrell Inc.,** 200 Washington St., Newark, N. J.

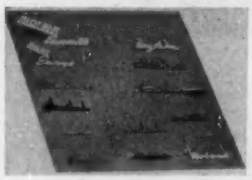


Circle 709 on page 19

Plastic Nameplates

have integral pins for fastening in place

Plastic pins, molded to back of nameplates, are long enough (to 1 in.) to allow mounting on sheet metal, plastic or plywood panel materials. Installation is by pressing



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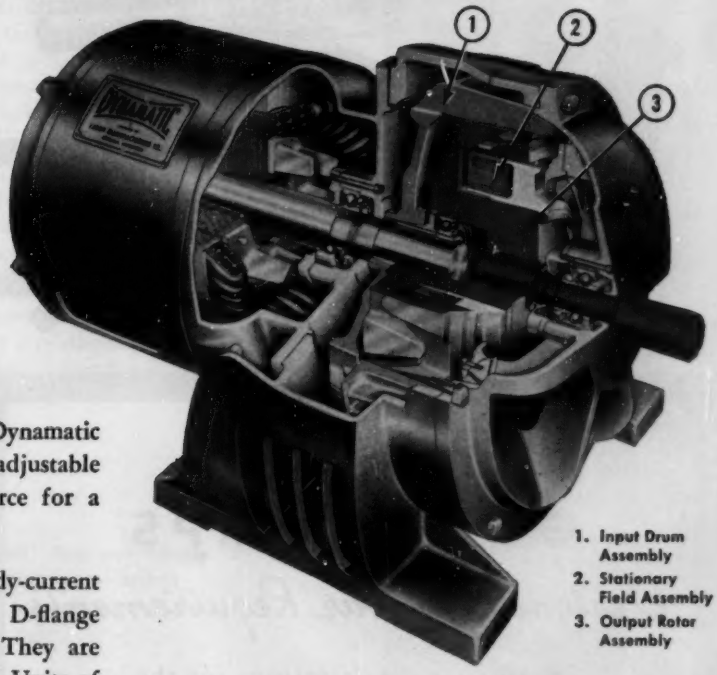

1. Input Drum Assembly
2. Stationary Field Assembly
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The newly announced stationary field Dynamatic Ajusto-Spede® Drives provide stepless adjustable speed from an alternating current source for a wide range of industrial applications.

These air-cooled, stationary field eddy-current couplings are mounted integrally with D-flange open drip-proof squirrel cage motors. They are available in capacities from 3 to 75 HP. Units of the same design and capacities are also available without motors.

This new stationary field design eliminates the use of rotating coils, brushes, slip rings, and commutators, holding wear and maintenance to an absolute minimum. Dynamatic electronic or magnetic amplifier controls, in combination with these drives, provide wide latitude in operating functions.

Investigate these Important Ajusto-Spede® Drive Advantages:

Accurate speed control • Wide speed range
Low power losses • Simple construction
Rapid response • Low maintenance cost
Quiet, efficient operation • Remote control

Send for Illustrated Literature Describing these New Stationary Field Drives

EATON DYNAMATIC DIVISION
MANUFACTURING COMPANY
3307 FOURTEENTH AVENUE • KENOSHA, WISCONSIN

Circle 483 on page 19

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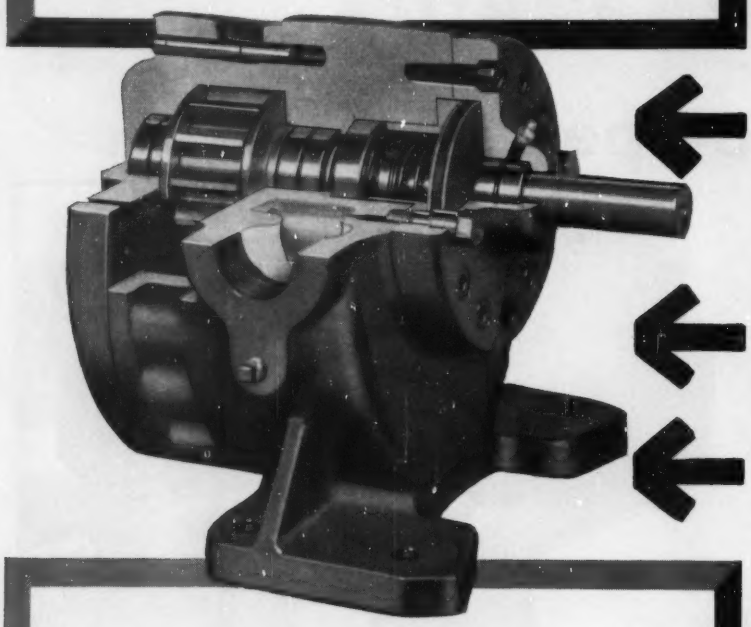
FLEXIBILITY



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New Parts

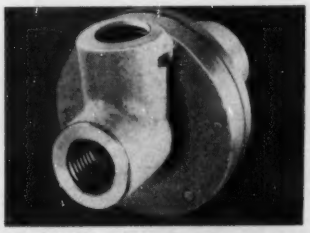
pins into molded or drilled holes, then applying heating iron from back to trim and melt over end of pins to seal nameplate in place. Plates are injection-molded Butyrate, Styrene, or similar material of any color. If desired, parts may be metallized to provide silver or gold finish. **V. H. Swenson & Co. Inc.**, 554-140 Elm St., Arlington, N. J.

Circle 710 on page 19

Gage Protector

permits accurate setting from 10 to 100 psi

Diaphragm-type gage protector, which protects gages from pressure surges, has fast response to pressure changes and automatically cuts out gage and bypasses working media when line pressures rise above spring setting in protec-



tor. Especially suited for air or poisonous gas service, the unit has an external pressure - adjusting control which permits accurate pressure settings from 10 to 100 psi. Protector is available with ¼-in. FPT part connections and has a corrosion-resistant brass body. **Superior Pipe Specialties Co.**, Superior Hydraulics Div., 15201 St. Clair Ave., Cleveland 10, O.

Circle 711 on page 19

Socket Mounting

for use in printed circuitry

Multiple right-angle socket mounting for printed-circuit use can accommodate two or more sockets, and also can be applied for mounting other electronic components, such as resistors and capacitors. Mounting incorporates either sockets of the same size or of varying sizes, and can be constructed to meet combinations and specifications required. Buttress-rib design

(Advertisement)

Helpful Data from DE LAVAL

How to calculate the efficiency of worm gearing

The efficiency of worm gearing is determined by frictional losses at the tooth contact, bearings and oil seals plus losses from oil churning and windage. A formula for efficiency at the tooth contact may be developed from a consideration of the forces at the contact. Figure 1 shows these forces acting on a developed section of the worm thread. For simplicity the pressure angle has been assumed to be zero.

The coefficient of friction of the worm and gear is a function of the materials, finish, lubrication and rubbing speed. The latter is the relative speed between a point on the pitch surface of the gear and one on the pitch surface of the worm. The coefficient of friction varies very little at high rubbing speeds but rises with increasing rapidity as the speed drops below 500 fpm.

The efficiency formula developed in Figure 1 involves worm lead angle and the friction angle. Figure 2 provides a relationship between friction angle and rubbing speed based on tests made on accurately manufactured gearing consisting of hardened and ground worm and bronze gear operating in oil.

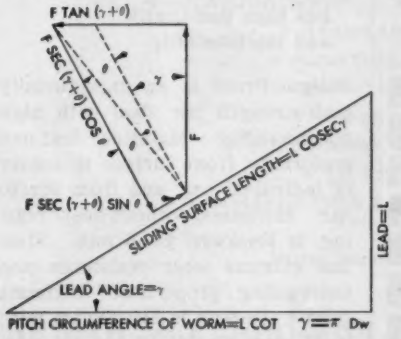
The formula for rubbing speed is:

$$V = \frac{.262\ Dw \times \eta}{\cos \gamma}$$

where

V = Rubbing speed – feet per minute
Dw = Worm pitch diameter – inches
η = Worm speed – rpm
γ = Worm lead angle

FIGURE 1.
Development of equation for efficiency at contact between worm and gear


F TAN (γ+θ)
F SEC (γ+θ) COS θ
F SEC (γ+θ) SIN θ
SLIDING SURFACE LENGTH=L COSEC γ
LEAD=L
LEAD ANGLE=γ
PITCH CIRCUMFERENCE OF WORM=L COT γ=π Dw

F=TANGENTIAL FORCE ACTING ON GEAR

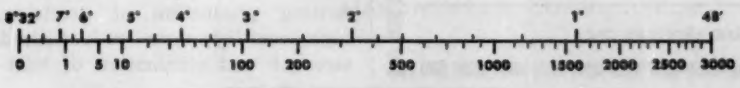
F TAN ($\gamma + \theta$) = TANGENTIAL FORCE APPLIED TO WORM

F SEC ($\gamma + \theta$) COS θ = FORCE NORMAL TO CONTACT SURFACE

F SEC ($\gamma + \theta$) SIN θ = FRICTIONAL FORCE

$$\text{EFFICIENCY} = \frac{\text{WORK REALIZED}}{\text{WORK APPLIED}} = \frac{L \times F}{L \cot \gamma \times F \tan (\gamma+\theta)} = \frac{\tan \gamma}{\tan (\gamma+\theta)}$$

FIGURE 2.



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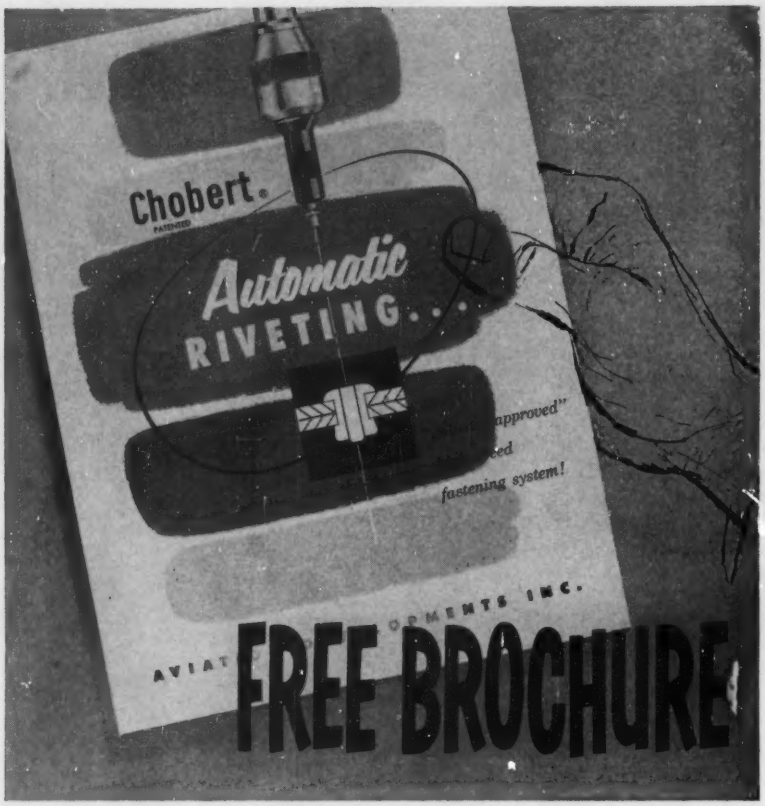
DE LAVAL Worm Gear Speed Reducers Offer Efficiencies to 96%

Ruggedly built for long efficient service De Laval speed reducers are made in horizontal and vertical single reduction units in ratios of 3:1 to 100:1. They are also available in double horizontal and vertical double reduction units as well as in helical-worm and double-worm design. Ratios from 37.8:1 up to 6400:1.

Write for your copies of Catalogs G-WBV and G-WWH to De Laval Steam Turbine Company, Trenton 2, New Jersey.



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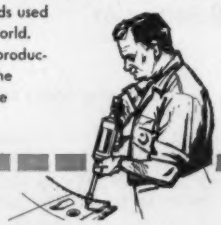

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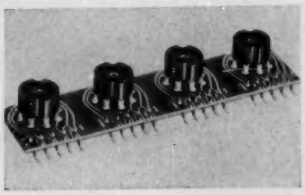
New Parts



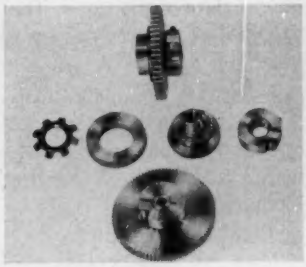
provides high structural rigidity and shock and vibration resistance. Mounting can be used on either side of the laminate base. **Cleveland Metal Specialties Co.,** 1783 E. 21st St., Cleveland 14, O.

Circle 712 on page 19

Miniature Slip Clutch

stainless-steel unit has bore of ⅛ or 3/16-in.

Miniature slip cultch has gear with diametral pitch of 48, 64, 72, 80, 96 or 120. Pitch diameter of gear



ranges from 0.750-in. to 1.500 in. Overall length is 0.562-in.; bore is 0.125 or 0.1875-in. Torque setting is by adjustable, threaded locking clamp which is set to desired torque reading. **Dynamic Gear Co., Inc.,** 20 Merrick Rd., Amityville, N. Y.

Circle 713 on page 19

Fatigue-Resistant Steel

has high uniformity and machinability

Fatigue-Proof is an exceptionally high-strength bar steel with high machinability. Material features uniformity from surface to center of individual bar, and from bar to bar. Hardness, without heat-treating, is Rockwell C 30 min. Steel has extreme wear resistance and antiwelding properties. Ultimate tensile strength is 140,000 psi min; yield strength is 125,000 psi min. Material is readily machined, permitting production of precision, high-accuracy parts with desired strength and elimination of heat-

For today's advanced

machine tools

Such as BULLARD MAN-AU-TROL
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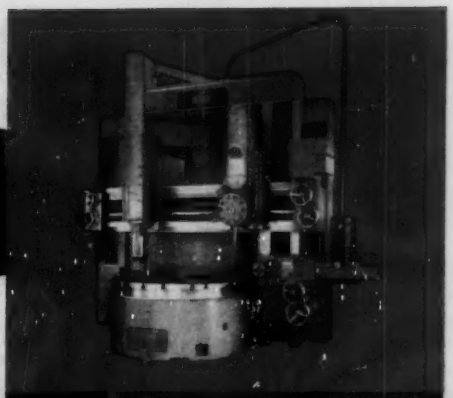
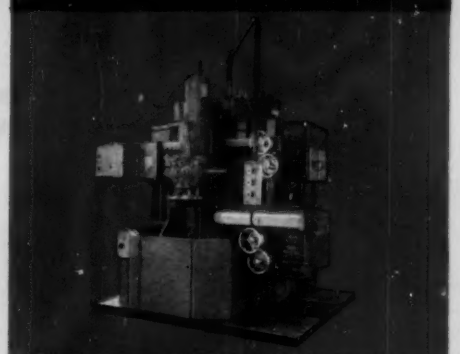
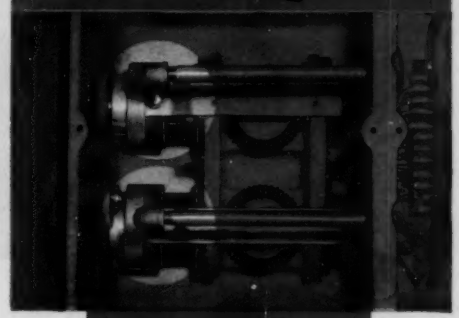


Above: Maxitorq Single and Double Electric Clutches on Bullard Cut-Master Model 75 Machines with single angular turning attachment.

Below: 4 Maxitorq Single Electric Clutches on Bullard Man-Au-Trol Model 75 Machines with double angular turning attachment.





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Compact, simple in design and construction, fully service-tested, this entirely new clutch design is ideally suited . . . as these Bullard applications show . . . to the new requirements of machine control. Here are the LONG-PROVED advantages of the famous Maxitorq Floating Disc Clutch, now electrically operated, and with these outstanding features . . .

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need quick service on TIMERS for automatic control?

Time Delay Timers

The more automatic control problems we get, the better we like it. For while it's true each automatic control job is a bit different from the rest, the record shows that our 19 years of timer experience has given us the special knowledge it takes to give you the right answers, and in near-record time.

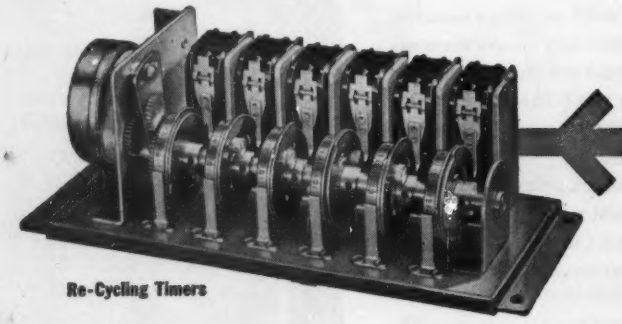
If one of our standard timers won't do your job — or one of the 721 combinations we have thus far developed from our 17 basic units — our engineers will go right to work to develop a new combination that's the one for you. That's the way we grow — and we like it.

We manufacture a complete line of timers in these 4 broad classifications:

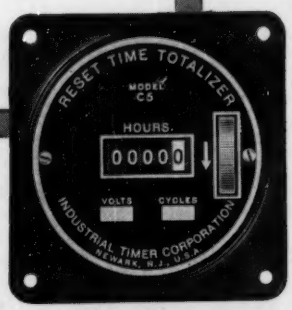
TIME DELAY TIMERS • INTERVAL TIMERS
RE-CYCLING TIMERS • RUNNING TIME METERS

And since we maintain large stocks of our 17 basic units, we can assure you of rapid deliveries — of excellent deliveries even on special orders. So whatever your automatic control problem, you have everything to gain by submitting it to our timer specialists. They'll give you a profitable answer — almost with the speed of automatic control itself.

Interval Timers



Re-Cycling Timers



Running Time Meters

Timers that Control the Pulse Beat of Industry

INDUSTRIAL TIMER CORPORATION

INDUSTRIAL TIMER CORPORATION
1413 McCARTER HIGHWAY, NEWARK 4, N. J.

treating and subsequent straightening, grinding, and other operations. Fatigue-Proof is suitable for use in environmental temperature to 600 F. Steel is available as bar stock or as ground and polished shafting. **LaSalle Steel Co.,** Box 6800-A, Dept. T-12, Chicago, Ill.

Circle 714 on page 19

Hydraulic Manifold

in two and three-station types

New cast-aluminum manifold provides efficient multiple mounting of two, three or four-way valves in any desired combination. Available in two and three-station types, with ¾ or ½-in. NPT cylinder ports, the manifold has full-length inlet and exhaust ports, both 1 in. NPT, common to all valve stations. Electrical wiring is run through a 1¼-in. NPT conduit passage, with

one access cover for all stations. Pilot-solenoid leads are enclosed in dirt and moistureproof flexible conduit. Manifolds can be ganged to afford uniform mounting of from two to six or more valves. Kits of O-rings and through-bolts for ganging manifolds are available. Manifold permits use of a centralized lubricating and filtering air supply system. **Valvair Corp.,** 454 Morgan Ave., Akron 11, O.

Circle 715 on page 19

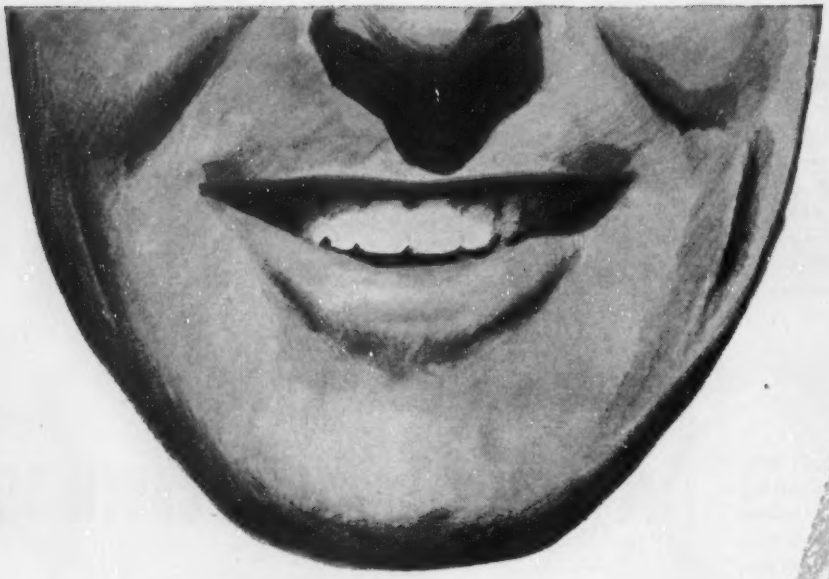
Motor-Generator Set

has 2500-w output

Small, lightweight motor-generator set converts direct current to alternating current. Motor and alternator are encased within a common frame with single-shaft, ball-bearing construction. Machine operates at 1800 rpm. Generator output is 120 v, single-phase, 60 cycle,

(*Continued on Page* 170)

there's a
"look of tomorrow"
in
MODERN GRAY IRON CASTINGS
Underneath the exteriors of each of "tomorrow's" automobiles, you'll find a quarter of a ton of gray iron castings. Progressive designers and purchasing agents in other industries are also taking a new look at modern gray iron utilizing its characteristics to keep pace with modern designs. These keen buyers realize that it is often more costly to duplicate the engineering properties of gray iron with competitive materials. Consider gray iron castings first in the design and purchase of parts for modern products.
Buy from reliable foundries displaying the GIFS symbol! Write for Buyers' Guide and Directory of members.
With modern gray iron castings you have a choice of over 30 types of metallic and non-metallic coatings.
it's time to design with
GRAY IRON CASTINGS
GRAY IRON FOUNDERS' SOCIETY, INC.
National City-East 6th Bldg. • Cleveland 14, Ohio



R & M MOTOR PARTS

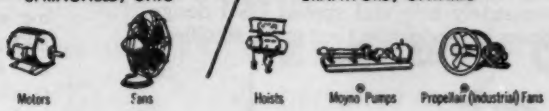
...put Extra
Customer Satisfaction
in the heart of
your product!

Your customers get added satisfaction where it counts because every R & M motor part is carefully designed and precision manufactured to provide dependable power at the flick of a switch . . . even after years of rugged use!

R & M's broad line and experience as major suppliers of standard motor parts to hundreds of manufacturers since 1928 assure you of sound judgment in recommending the correct motor parts for your application. You will find R & M application engineers well qualified and eager to work with you on any application requiring series, universal or polyphase high-cycle motor parts. Write today for R & M bulletin 455-MD and the name of the R & M Field Engineer in your area.

ROBBINS & MYERS, INC.

SPRINGFIELD, OHIO / BRANTFORD, ONTARIO



Motors Fans Hoists Moyno® Pumps Propellair® (Industrial) Fans

Circle 489 on page 19

...may be answered

by one of more than

50,000 standard USG gauges

Eliminating the expense of special gauge design and manufacture is an important factor in reducing production costs. To keep costs low on "special" gauge designs, USG is tooled for more than 50,000 different standard gauges. Many of these are of unique design and application. It is possible that with slight modification one or more of them will exactly meet your design requirements and save you important time and costs.

The U. S. Gauge background of over 50 years of gauge design and manufacture assures you the experience and resources that make possible an easy solution to special gauge applications.

Why not call the nearest USG Distributor or write the factory direct to determine whether we can supply a standard to your specifications, a modified standard, or whether or not your problem will actually require a completely new and special USG design. The call might save you hours in production time and a significant savings in cost.

UNITED STATES GAUGE

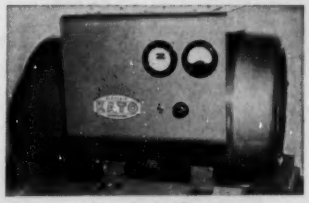
Division of American Machine and Metals, Inc.
Sellersville, Pa.

Home of the SUPERGAUGE

New Parts

(*Continued from Page* 167)

2500 w. Motor voltage range is 27½ to 29 v. Lee governor con-



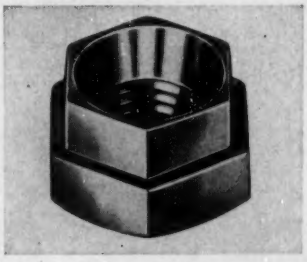
trols motor rpm. Instrument panel includes frequency meter, ac voltmeter and input voltage control rheostat. Unit is 28 [illegible]ng and 17 in. high. **Kato Eng[illegible]ng Co.,** 1415 First Ave., Mankato, Minn.

Circle 716 on page 19

Clinch Nuts

are available in small sizes

Gripco clinch nuts are available in sizes from No. 4 through ¼-in., with or without locking feature. All sizes, including No. 10 through



⅝ in., are available in both fine and coarse threads. Dimensions of the No. 10 size and the ¼-in. size have been reduced across flats and clinching collars. **Grip Nut Co.,** South Whitley, Ind.

Circle 717 on page 19

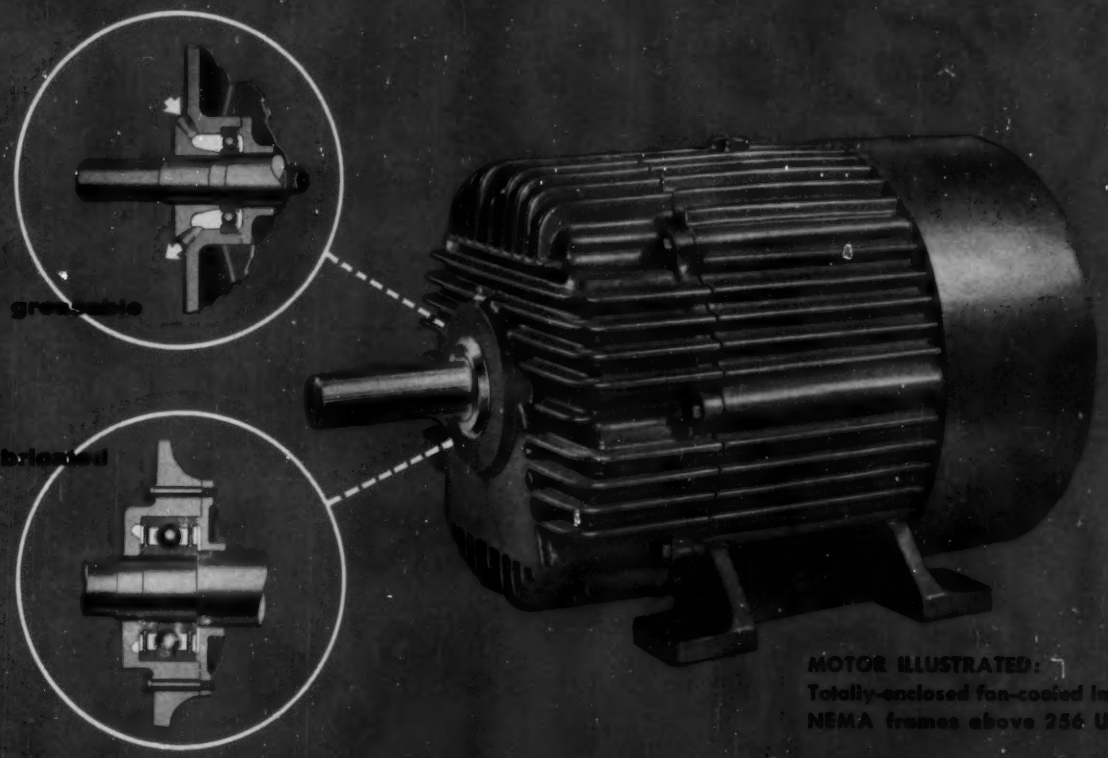
Electronic Counter

operates with many types of pickups

Preset counter for industrial counting applications counts from 0 to 5000 cps without adjustment or circuit changes. Counter is extremely flexible and will operate with photoelectric, semiconductor, magnetic, or contact-making pickups. At end of warning and final count, plug-in relays are energized for control purposes. Warning circuits can be used to slow a process to

Circle 490 on page 19

YOUR CHOICE of motor bearings . . .



—when you specify ELLIOTT Crocker-Wheeler Type N integral horsepower motors

Whatever your operating conditions or maintenance practice, Crocker-Wheeler offers the motor bearing best adapted to your needs or preference.

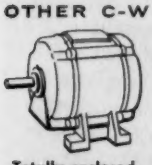
The Open Greasable type
requires only infrequent lubrication. All old grease is positively flushed out, eliminating risk of forcing grease into motor interior. An external grease reservoir helps seal and protect the bearing. The inner cap and grease reservoir prevent rust or corrosion from within.

Prelubricated bearings
are furnished for applications requiring operation without regular service lubrication. They are sealed cartridge-type, factory grease-filled, with inner protective cap.

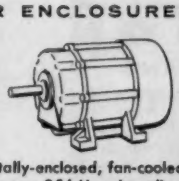
Choice of bearings
is another design feature of the new Elliott Type N motor line. These motors are honestly new—inside and out. We think you'll agree that they incorporate every important feature that distinguishes a modern motor.

W7-1

OTHER C-W TYPE N MOTOR ENCLOSURES


Totally-enclosed non-ventilated

Dripproof Protected


Totally-enclosed, fan-cooled Frames 256 U and smaller

ELLIOTT Company
CROCKER-WHEELER DIVISION
Jeannette, Pennsylvania

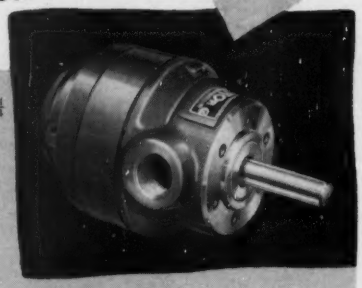
We will be glad to send a copy of this new booklet describing the complete line of Elliott C-W type N motors. Ask for Bulletin PB 6000-6.

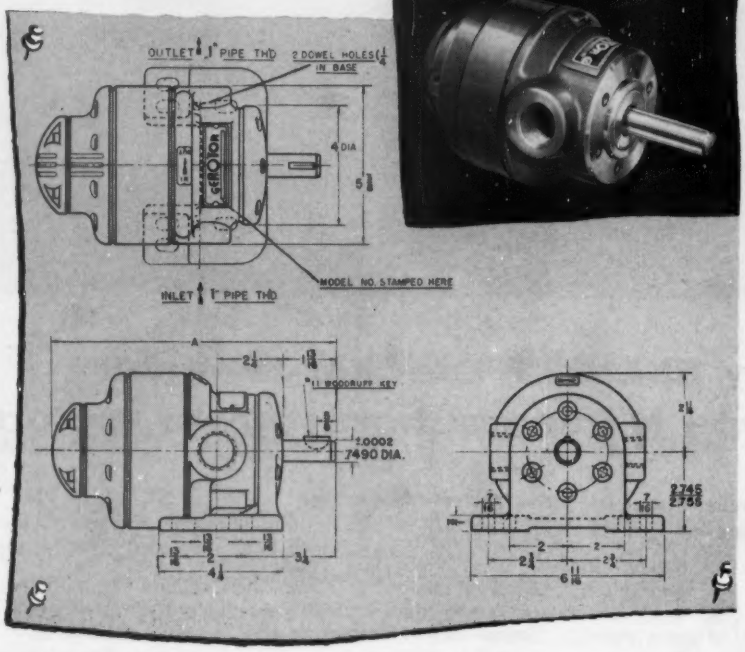
Circle 491 on page 19

Immediate Delivery on all Gerotor Hydraulic Pumps

- Built to J.I.C. Recommendations
  (check dimensions below)
- 2000 lbs. relief valve settings . . . up to 12 g.p.m.
- Choice of 2 speed ratings . . . 1200 or 1800 r.p.m.

Gerotor Hydraulic Pumps DELIVER more oil for less H.P.





Consult your GEROTOR distributor. Free literature on request . . . write:

Progress Through Fluid Power by—

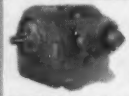
GEROTOR

MAY CORPORATION

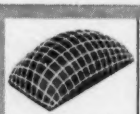
MANUFACTURERS OF—

OWINGS MILLS, MARYLAND

Hydraulic Pumps and Motors



Variable Speed Hydraulic Transmissions



PneuBin—Pneumatic Bin Evacuators

New Parts

insure accurate control or to provide notice that preset number is

about to be reached. Counter can be reset manually or automatically. **Machinery Electrification Inc.,** Northboro, Mass.

Circle 718 on page 19

High-Temperature Alloy

withstands temperatures to 1400 F

Incoloy T titanium - nickel - iron-chromium alloy, for use in highly stressed parts of jet engine combustion systems, is a strong sheet material that withstands temperatures to 1400 F or higher in some applications. It is similar in composition to Incoloy nickel-iron-chromium alloy, with about 1 per cent titanium added. The material has excellent oxidation resistance at temperatures to 1600 F. At temperatures below 1200 F, tensile and rupture strengths can be improved by cold working. Since the alloy is usually fabricated into components where attachment by welding is necessary, cold working for increased strength is not recommended. **International Nickel Co. Inc.,** 67 Wall St., New York 5, N. Y.

Circle 719 on page 19

Lubricator

for machines requiring dual lubrication

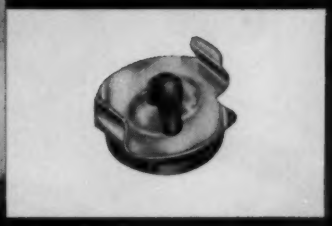
Two independent lubrication systems, providing both cyclic and continuous oil flow to different bearings on the same machine, are built into a single automatic lubricator, the AP-3. It consists of two independent gear pumps with a common drive gear, mounted in a single housing, both drawing oil from a common reservoir in bottom of the housing. Each pump has its

Circle 492 on page 19

DOT

THREAD CUTTING FASTENER
HOLDS TIGHT TO CURVED SURFACES

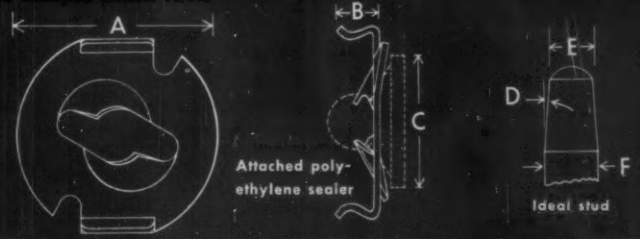
- Low Cost
- Re-Usable
- Self-Locking
- Vibration-Proof
- Spring Take-Up



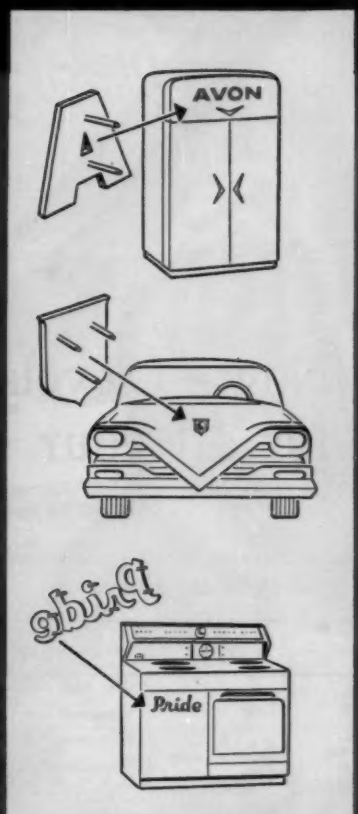
Specially designed to hold die-cast or cold-forged name plates, emblems and trim against sheet metal surfaces . . . DOT'S unique T.C.F. can be used in many other applications which require a spring take-up fastener that pulls up tight without lockup on flat or contoured surfaces.

It cuts clean, deep threads on unthreaded studs, even those that are chrome plated. When used with its preassembled plastic sealer, T.C.F. makes a water-tight seal. The sealer *precedes* the fastener onto the stud so that it is not damaged by the thread-cutting process.

Available *in quantity*, with or without sealer, to fit 1/8" and 3/16" studs. Drawings available on request for magnetic tool or simple hand tool.



Nominal Sizes	A	B	C	D	E	F	Driving Torque	Ultimate Strength
1/8"	.560	.170	.450	6°/4°	.095 .085	.130 .125	7-10 Inch lbs.	200 lbs.
3/16"	.705	.200	.450	6°/3°	.160 .150	.192 .184	20-30 Inch lbs.	400 lbs.

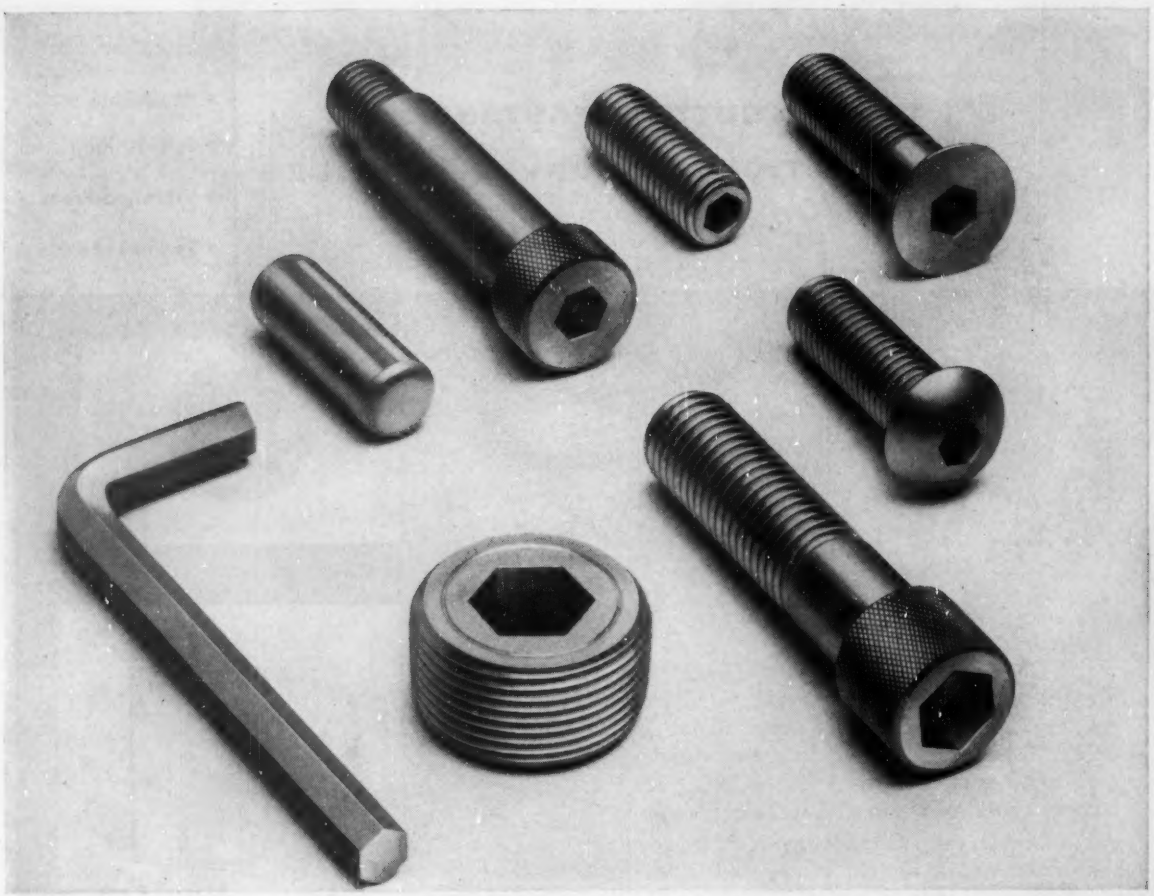


Manufactured by
MONARNOCK MILLS SUBSIDIARY
San Leandro, Cal.

DOT T.C.F.
Patent Pending

Manufactured by
CARR FASTENER CO. DIVISION
Cambridge, Mass.

UNITED-CARR FASTENER CORPORATION



Now—Cleveland provides a single source for all your socket screw requirements

Simplifies specification, cuts paper work, speeds delivery

CLEVELAND STANDARD SOCKET SCREW PRODUCTS
UNIFIED THREADS—CLASS 3A FIT

Type	Standard Sizes (diam.)	Material
Socket head cap screws	#0 to 1½ in. (larger sizes avail.)	Alloy steel, heat treated or Nonmagnetic 18-8 stainless
Set screws (cup, half dog, flat, cone or oval points)	#0 to 1 in. (#0-#3, cup point only)	Alloy steel, heat treated or Nonmagnetic 18-8 stainless (to ½ in., cup point only)
Flat head socket cap screws	#4 to ¾ in.	Alloy steel heat treated
Button head socket cap screws	#4 to ⅜ in.	same
Shoulder screws (stripper bolts)	¼ to ¾ in.	same
Dowel pins	⅛ to 1 in. (nominal size and .001 in. oversize for repair)	same
Pressure plugs	⅛ to 1¼ in. NPTF	same
Socket screw keys	.028 to 1 in. across flats; short or long arm	same

Cleveland has expanded its socket screw line to provide a single source for all your socket head needs.

At the same time, and in conjunction with opening its new plant, Cleveland is doubling its factory warehousing capacity. This, plus the latest materials handling equipment, will enable Cleveland distributors to get same-day shipment of your larger orders.

Included in the expanded Cleveland socket screw line are precision dowel pins. While not a socket head product, they are basic fasteners for the important tool and die industry, where they are closely associated with socket head cap screws and shoulder screws. We offer them as part of a complete service.

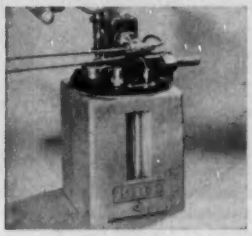
Cleveland socket head cap screws are upset forged from heat-treated alloy steel. This results in symmetrical, unbroken grain structure in heads, threads and fillets—greater fatigue and tensile strength, stronger fasteners.

Write for latest literature and technical data. Then see your local Cleveland Cap Screw distributor for all your socket screw requirements.

THE CLEVELAND CAP SCREW COMPANY
4444-6 Lee Road, Cleveland 28, Ohio

Circle 494 on page 19

own inlet and outlet, feeding oil through separate distribution systems to the bearings each serves. At each lubrication point a meter unit filters and measures exact quantities of oil fed to each bear-



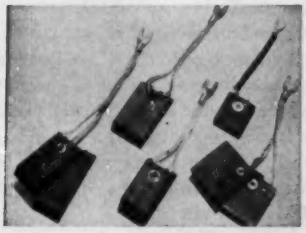
ing. Cyclic pressure ranges from 25 to 150 psi; continuous pressure range is 7 to 150 psi. Oil flow from the continuous branch is constant regardless of oil temperature. Both pumps are driven from the lubricator's drive shaft, which can be powered from the drive of the machine it is lubricating. Standard oil reservoirs have 3 or 6-pt capacity. **Bijur Lubricating Corp.**, 151 W. Passaic St., Rochelle Park, N. J.

Circle 720 on page 19

Graphitic Brushes

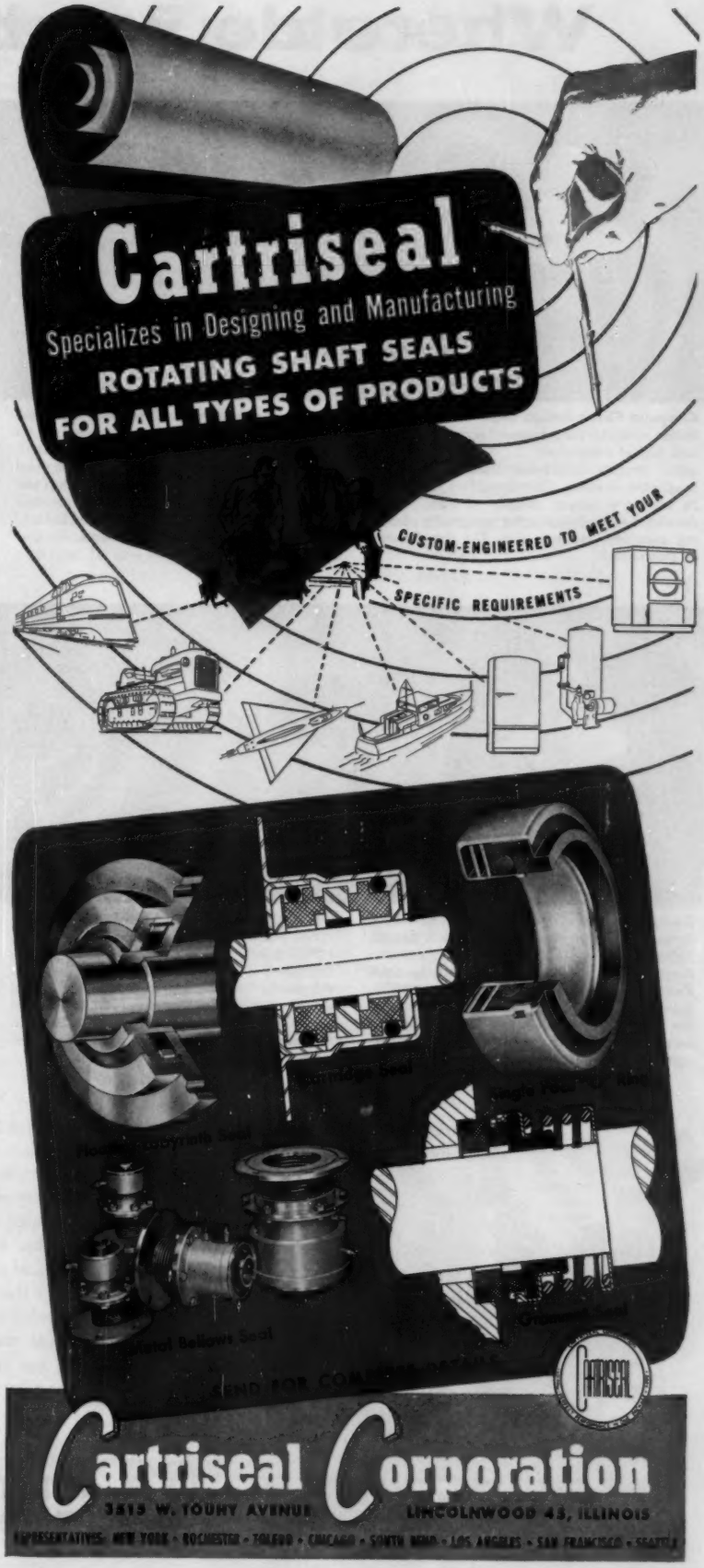
. . have high commutation factor

D series electrographitic lamp black brushes are designed primarily for dc motors and generators. They exhibit high contact drop, low friction and good carrying capacity. Grades of this series are recommended for ac and dc heavy-duty traction, locomotive, mill, mine, crane, elevator and elec-



tric shovel motors, and also for general service on dc generators and synchronous converters. Brushes possess a high commutation factor for severe commutating conditions. They possess necessary film-forming properties needed while operating under ad-

(*Continued on Page* 178)



Where do you belong in

Computer Circuit Design Engineers plan electronic circuitry for advanced airborne analog and digital computers . . . design linear and pulse circuits employing transistors, tubes, magnetic devices. Opportunities also exist in airborne power supply design, or to develop new techniques for marginally checking computer performance. *Do you belong on this team?*

Computer Logical Design Engineers determine the systems outline of a computer and its inter-connection with external equipment. Close liaison is maintained with mathematical support, circuit design, packaging and test engineers. Computer speed, memory size, configuration and arithmetic structure are tailored to requirements of weapons systems. *Do you belong on this team?*

Systems Evaluation Engineers test and evaluate electronic analog and transistorized digital computer systems design for aircraft; evaluate new systems and improvements to insure compliance with specifications and Air Force requirements. Other assignments: tie-in testing of peripheral equipment, liaison with design, development and field engineering. *Do you belong on this team?*

Harry Branning (center): B.S.E.E. 1950, Syracuse. Design Engineer in circuit design, 1951; October, 1954, promoted to Associate Engineer; April, 1956, promoted to Staff Engineer, Systems Planning. In June, 1956, appointed Project Engineer and Manager of the 110 Computer Circuit Design Department; discussing the performance and packaging details of a transistorized read amplifier.

William Dunn (standing): M.E. 1950, M.S.E.E. 1952, Stevens Institute. Technical Engineer, 1955; April, 1956, promoted to Associate Engineer; August, 1956, transferred to Development Engineering in charge of Logical Design for digital computers in advanced weapons systems; here discussing Boolean Algebra method of optimizing the logical design of an airborne digital computer.

Eli Wood (left): B.S.E.E. 1950, Connecticut. IBM Customer Engineer, July, 1950; September, 1952, transferred to ACL Field Engineering. February, 1954, in charge of Field Engineering at Hunter AFB; May, 1955, Associate Engineer; appointed Project Engineer, Manager of Systems Evaluation in August, 1956; here investigating a problem in radar data presentation set evaluation testing.

The brief records of the men cited above indicate only a few of the exciting activities right now in IBM Military Products. This division, organized 18 months ago, has grown enormously. A small-company atmosphere prevails. Men work in small teams . . . individual contributions are instantly recognized. Promotions occur frequently.

As a member of IBM Military Products, you'll enjoy physical surroundings and equipment second to none. Educational programs at IBM expense lead to advanced degrees. Salaries and benefits are excellent. Stability is guaranteed by IBM's history of consistent achievement—underlined by the fact that the rate of turnover at IBM is only one-sixth the national average.

Throughout the length and breadth of the United States IBM has built modern plants and laboratories. This map points out the various locations where you might live as an IBM em-

DATA PROCESSING
ELECTRIC TYPEWRITERS
TIME EQUIPMENT
MILITARY PRODUCTS

IBM MILITARY PRODUCTS

IBM Military Products?

Systems Engineers oversee the engineering support provided by the Systems Coordination and Specification Group to the factory on the AN/ASB-4 Bombing-Navigational System. Air Force requirements are analyzed and the resulting engineering changes evaluated to determine effect on system performance and accuracy. Mathematical error analyses are run. *Do you belong on this team?*

Systems Analysts anticipate performance and recommend design criteria before and during development of equipment. Later, they compare dynamic performance accuracy and reliability characteristics with what has been anticipated. Other assignments include Digital Computer Systems Engineering, Input-Output and Analog-Digital Conversion Engineering. *Do you belong on this team?*

Quentin Marble (left): B.S.M.E. 1951, Syracuse. Joined IBM in 1951; promoted to Design Engineer in 1952; May, 1955, promoted to Associate Engineer, and then to Project Engineer, Manager of the Systems Coordination and Specification Group, Production Engineering Department, in February, 1956; shown here describing a unique cooling design to a new employee in his group.

Monroe Dickinson (left): B.S.E.E. 1952, W.P.I.; M.S.E.E. 1954, M.I.T. Technical Engineer in analog and alternate computer techniques for weapons systems, 1952; Associate Engineer responsible for systems design and analysis, 1954; December, 1955, Staff Engineer, responsible for research planning; here reviewing set-up on laboratory analog computer of a sampled data control problem.

Exceptional career opportunities are now open in IBM Military Products for E.E.'s, M.E.'s, physicists, and mathematicians, in the following fields:

SYSTEMS PLANNING AND ANALYSIS
DIGITAL AND ANALOG SYSTEMS
INERTIAL GUIDANCE
SERVO-MECHANISMS
ELECTRONICS
MECHANICAL DESIGN
ELECTRONIC PACKAGING
PROGRAMMING
FIELD ENGINEERING
RELIABILITY
COMPONENTS
PHYSICS
MATHEMATICS
HUMAN ENGINEERING
INSTALLATION
CIRCUIT DEVELOPMENT
POWER SUPPLIES
TRANSISTORS
HEAT TRANSFER
OPTICS
TEST EQUIPMENT
COST ESTIMATING
TECHNICAL PUBLICATIONS

ployee. IBM Military Products include the Airborne Computer Laboratories located in Owego, N. Y., and the Project SAGE installations directed from Kingston, New York.

Here is a real ground-floor opportunity that you can't afford to overlook. Without exaggeration, your potential in this dynamic young field of electronic computers is virtually unlimited. Get all the facts. Write, outlining your background and interests to:

R. A. Whitehorne
Manager of Engineering Recruitment, Dept. 8902
International Business Machines Corp.
590 Madison Ave., New York 22, N. Y.

Circle 496 on page 19

HANSEN SERIES RL
★ ★ ★
EFFECTIVELY HANDLES MORE VOLUME THAN ANY OTHER COUPLING OF EQUAL DIMENSION

HANDLES ANY APPLICATION ON AIR CIRCUITS REQUIRING ⅛" TO ¾" CONNECTIONS

Smaller!

Lighter!

HANSEN

SERIES RL

QUICK-CONNECTIVE

RING-LOCK COUPLINGS

Hansen Series RL One-Way Shut-Off Couplings will handle any application on air line circuits requiring ⅛" to ¾" connections. All Hansen Series 2-RL Sockets and Plugs are interchangeable with each other. Likewise, all Sockets and Plugs of the slightly larger, greater capacity Series 3-RL are similarly interchangeable with each other.

Consequently, by standardizing on either Hansen Series 2-RL or Series 3-RL Couplings, you make it easy for users of your product to keep stock of parts in balance – hold inventories to a minimum.

Locking ring provides positive lock and assures tight fit. Equipped with automatic sleeve lock.

Two-Way Shut-Off and Straight-Through Couplings also available.

WRITE FOR CATALOG

SINCE 1915 QUICK-CONNECTIVE FLUID LINE COUPLINGS

THE HANSEN MANUFACTURING COMPANY

4031 WEST 150th STREET • CLEVELAND 11, OHIO

New Parts

(*Continued from Page* 175)

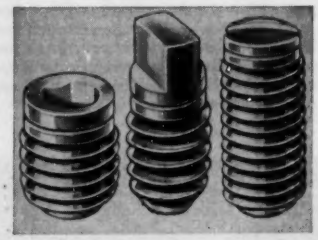
verse atmospheric conditions. **Ohio Carbon Co.**, Dept 281, 12508 Berea Rd., Cleveland 11, O.

Circle 721 on page 19

Setscrew

has self-locking action

Crest-Lok self-locking setscrew utilizes locking action provided by an unthreaded portion of the crest and eliminates need for precise hole tapping. Amount of locking action can be controlled by changing tap drill diameter; repeated re-



use does not affect locking action. An unthreaded portion at the crest of the setscrew is approximately pitch diameter size and compresses the crest of the threads in the tapped hole when driven flush. The screw is available in any size headless setscrew, socket, fluted, slabbed and slotted, in standard or special points. **Set Screw & Mfg. Co.**, Bartlett, Ill.

Circle 722 on page 19

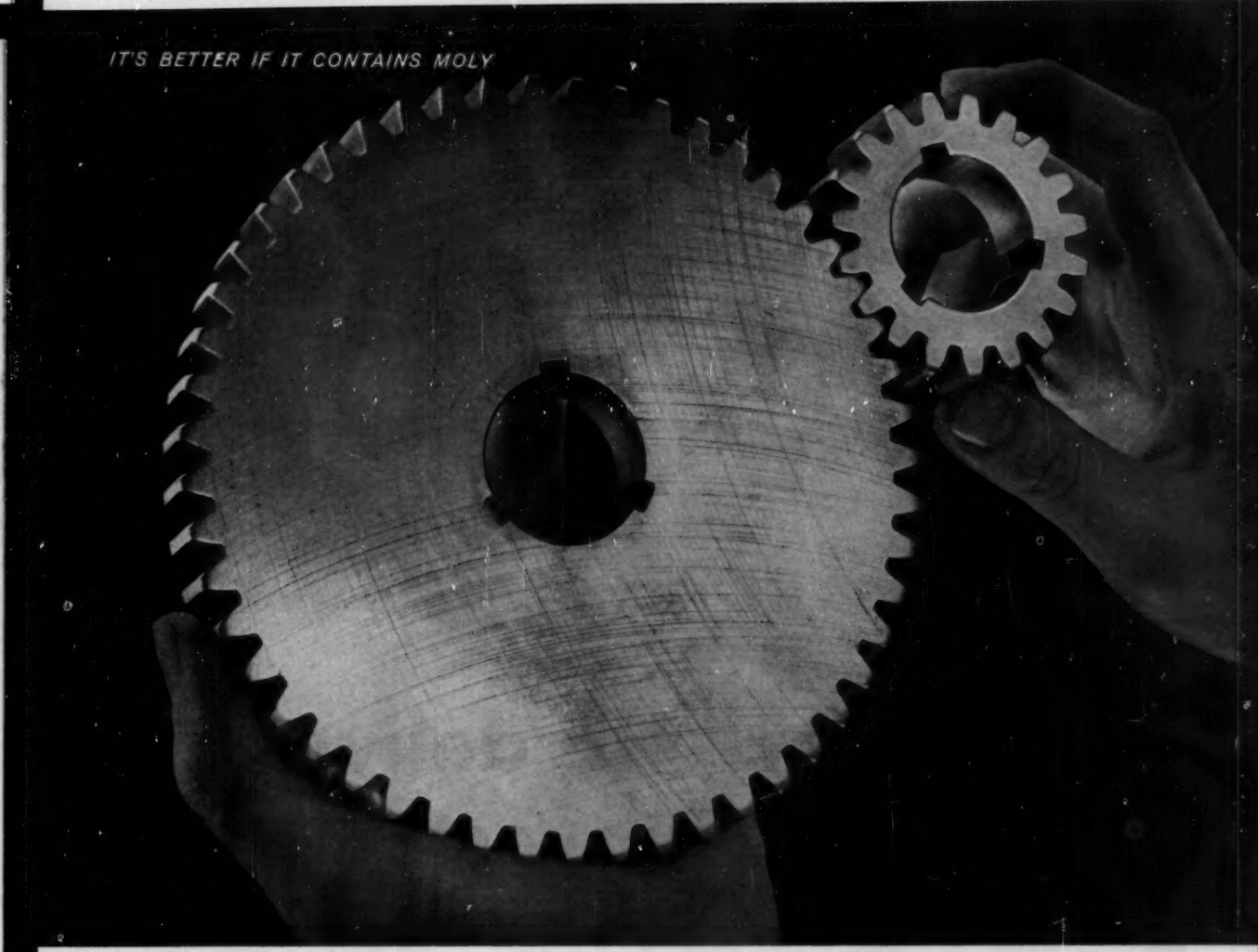
Waveguide Components

of oxygen-free high-conductivity copper

Straight sections, circular bends and adapters are available in the WR-137 waveguide size. Used in combination with standard flexi-

ble waveguide components and windows, they lend themselves to installation in microwave relay systems operating in the 6000 mc region. Components, because of their high conductivity, have applications in indoor and outdoor cabinet arrangements. High con-

IT'S BETTER IF IT CONTAINS MOLY



Up to 1% Moly in carburizing steels gives required hardenability economically

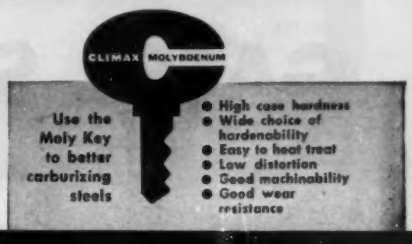
Why limit the use of molybdenum to the .15/.25% Mo and .20/.30% Mo contents of the traditional grades? For the contributions of moly do not stop there. Laboratory tests and production runs prove that as molybdenum contents increase up to 1%, hardness increases progressively. A wide range of case and core hardenabilities, therefore, can be obtained – economically, too.

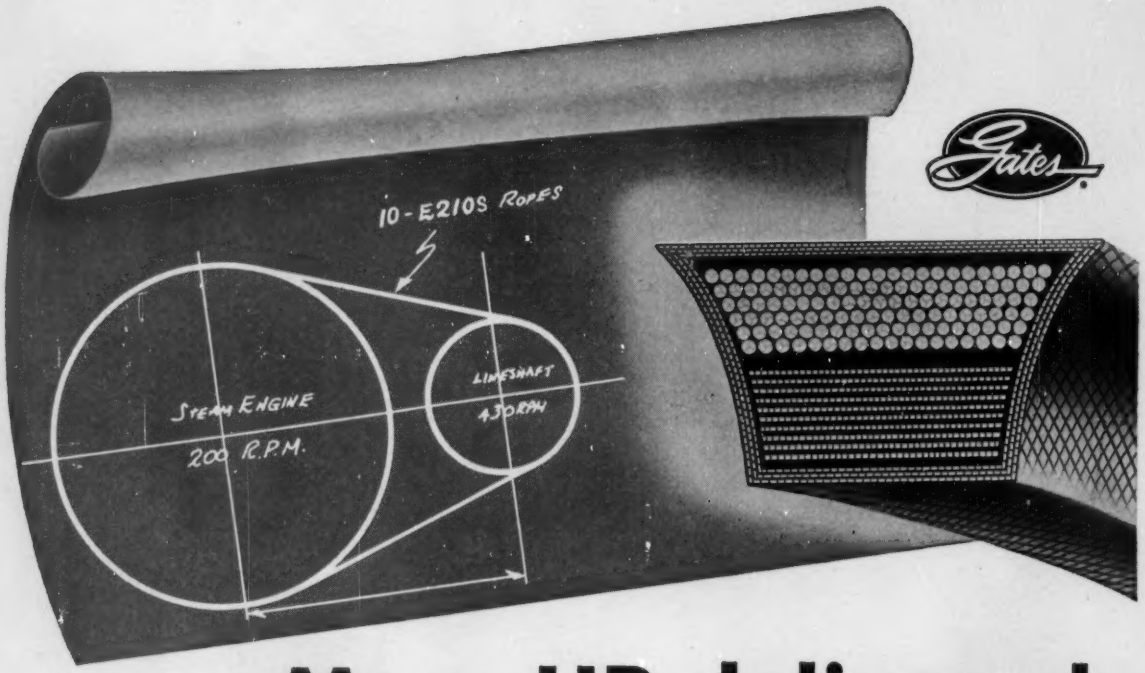
Tests with a series of molybdenum-manganese steels show that these compositions give higher case hardness on a direct quench than other steels of comparable core hardenability. One extensively tested composition, for example, is 0.5% Mo – 0.5% Mn steel. It shows longer life, and is lower in cost than steels previously used. And it produces a higher case hardness with similar or less distortion. What's more, tool life and surface finish are equal or better. Good reasons why several companies have already adopted this grade for automotive gears and other critical applications.

If you use carburizing steels, see what a higher molybdenum content can do for you. Part of the story is contained in the technical article "New Carburizing Steels For Critical Gearing." For your copy, or other technical data, write Climax Molybdenum Co., Dept. 11, 500 Fifth Avenue, New York 36, N. Y.

CLIMAX MOLYBDENUM

Circle 498 on page 19





More HP delivered per $ invested

On any new drive design—where you have limited space or you need to keep weight down—here is an important fact that can save you money:

A Gates Super Vulco Rope drive will deliver more horsepower per dollar invested than any standard V-belt drive.

Actually, the greater load carrying capacity of Super Vulco Ropes cuts down the number of belts required (5 Super Ropes do the work of 7 standard belts) . . . thus reducing the width of sheaves.

Sheaves with fewer grooves not only cost less, they weigh less, and take up less room—advantages that can easily improve the design and lower the overall cost.

A wealth of drive data is quickly available to you. Simply call your nearby Gates V-Belt Distributor (see 'phone book yellow pages) for a Gates V-Belt Specialist. Stocks available in industrial centers around the world. The Gates Rubber Co., Denver, Colorado—*World's Largest Maker of V-Belts.*

4 BIG PLUSES

✚ Handles shock loads

Super-strength cords provide 40% greater horsepower capacity . . . easily absorb heavy shock loads.

✚ Provides Static Safety

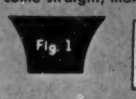
High electrical conductivity is built into Gates Super Vulco Ropes for safer drives (in explosive atmospheres).

✚ Resists oil, heat and weather

Special rubber compounds with which cords and fabric are impregnated make Super Vulco Ropes highly resistant to heat, oil and prolonged exposure.

✚ Wears far longer

Concave Sidewalls (Fig. 1) increase belt life. As belt bends, concave sidewalls (U.S. Pat. No. 1813698) become straight, make uniform contact with sheave groove (Fig. 1-A). Uniform contact means less wear on sides of belt . . . longer V-belt life.



Flex-Weave cover (U.S. Pat. No. 2519590) provides greater flexibility with far less stress on fabric. Cover wears longer—increases belt life.

TPA 76A

GATES SUPER VULCO ROPE DRIVES

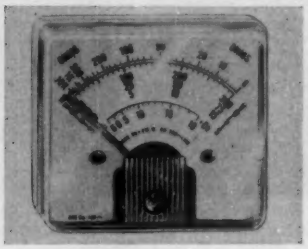
ductivity results in a low insertion loss for extended waveguide runs. Copper has a waveguide attenuation between 2.0 and 2.4 db/100 ft. **Airtron Inc.**, Dept. B, 1103 W. Elizabeth Ave., Linden, N. J.

Circle 723 on page 19

Panel Meters

have clear plastic cases for easy dim-light reading

Type PS-250 panel meters have transparent plastic cases of standard sizes and mounting provisions. D'Arsonval-type movements are used in dc microammeters, milliam-



meters, ammeters, millivoltmeters, voltmeters, ac microammeters and ac milliameters. Accuracy is 2 per cent full scale. **Waters Mfg. Inc.**, Box 368. South Sudbury, Mass.

Circle 724 on page 19

Actuator

for temperatures from −67 to 600 F

Stainless-steel actuator for aircraft applications is hydraulically operated over a range of pressures from zero to 3000 psi. It can be adapted to pneumatic operation to meet requirements of certain in-

stallations. Designed to operate within a temperature range from −67 to 600 F, the actuator uses no O-rings but incorporates high-temperature seals. Prototypes, such as that shown, have a stroke of 7 in. They are 16 in. long and 2⅜ in. in diameter. Basic design

(*Continued on Page* 184)

INSTANT CONTROL FROM ANY ANGLE!

On operations where instant control is imperative install a mushroom-head pushbutton. Even a gloved hand can find it easily from any angle in every emergency. One fast push and you are in command.

Westinghouse mushroom heads are available in a wide range of colors and materials... the popular red plus seven other shades of homogeneous, longer wearing plastic. For more rugged applications there are the anodized aluminum buttons in plain, black and bright red.

In Westinghouse Oil-Tite* controls, both operators and enclosures are moistureproof. A tight rawhide seal around the stainless steel operating shaft prevents oil and other harmful liquids from reaching electrical connections. And drainage holes will not allow liquids to be trapped in the housing. Enclosure covers are tightly gasketed with mounting holes in separate wells. Oil simply cannot seep in.

These pushbuttons are tailored to your needs... at standard prices. All parts are interchangeable permitting minimum stocking of components.

Booklet B-7022 will tell you more about Oil-Tite controls, and the new 72-page pushbutton guide B-6749 will give you information on the complete line. Write to Westinghouse, Box 868, Pittsburgh 30, Pa. *Trade-Mark

J-30251

YOU CAN BE SURE... IF IT'S Westinghouse

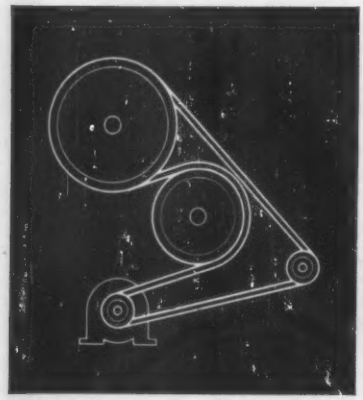
Circle 500 on page 19

V-Belt Designer's Notebook

A special V-Belt Engineering Service to help you cope with 7 Drive Problems created by space-saving modern design

A checklist of V-belt drive designs which require specialized engineering. With a description of the compensating characteristics which can be built into special Dayton V-Belts. Sources: Case histories from the files of the Dayton Special V-Belt Engineering Service and "The Dayton Handbook of V-Belt Drive Design and Selection."

Here's a typical example of efficient, compact, modern design—an automatic washer with a Dayton V-Belt Drive.

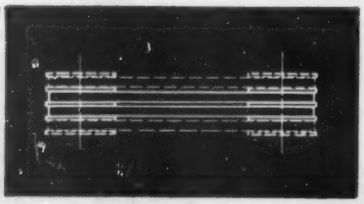


Note that it imposes three design requirements, (1) a torturous back bend (2) sub-diameter pulleys (3) a limited tension take-up area. Yet the design is efficient because Dayton V-Belt engineers developed a belt especially adapted to these three punishing conditions.

You'll find similar examples in machine tools, agricultural machinery and wherever drive space is limited. You've seen them yourself—the designs which dictate sheave misalignment, back-side idlers, underbelting; plus others which use V-Belts as a clutch and which impose excessive shock loads on the belt.

HERE ARE THE MAJOR CONDITIONS WHICH AFFECT V-BELT PERFORMANCE

Underbelting

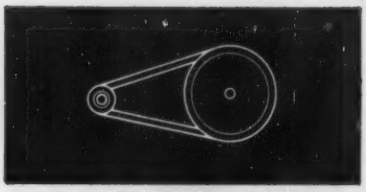


Underbelting is found where space is limited or as a result of very low belt speeds. It will cause belts to slip, run hot and wear out very quickly. A temporary cure, commonly employed, is to over-tension the belt – thus throwing excessive loads on the bearings.

The design requires a high capacity belt with extra-strength cords found in Dayton's Super-Thorobred series or, in difficult cases, belts with both a high coefficient of friction and extra strength like the raw-edge Dayton Cog-Belt.

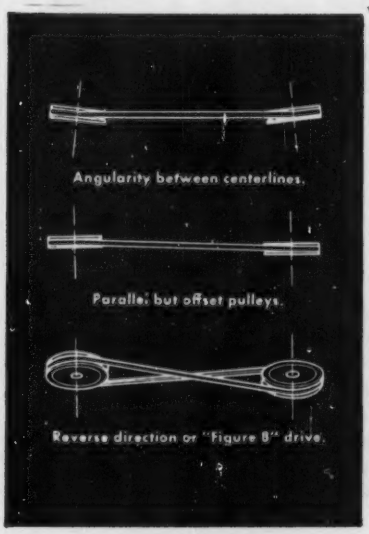
Sub-diameter sheaves

Belts driven by sub-diameter sheaves are inclined to succumb to accelerated flex failure. Tensioning problems are a usual result.



Sub-diameter sheaves require extremely flexible belts for satisfactory service. The required flexibility may be obtained by using thin V-Belts—where drive capacity is not high. When considerable capacity is required, Dayton Cog-Belts will give the most satisfactory performance. Their exclusive design permits exceptional flexibility. Die-cut raw edges provide high coefficient of friction, transmit maximum power from sub-diameter sheave arcs.

Misalignment

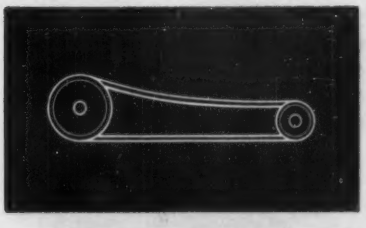


(Advertisement)

Misalignment causes uneven tension across the face of the belt—producing abnormal belt and pulley wear and uneven bearing loads.

A suitable approach is to use highly extensible cords of the latest synthetic fibers in the strength band of the V-belt. Dayton's Development Engineer can prescribe the material best suited to your needs.

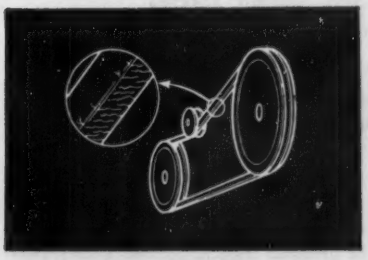
Fixed centers



Proper tension cannot be maintained with fixed centers or where center distance adjustment is inadequate. Without proper tension, belts slip and need frequent replacement.

Dayton V-Belts with low-stretch neutral-axis cords are best suited for applications with little or no provision for center distance adjustment. Still higher performance is gained if the belts have maximum cross-sectional stability which helps keep the belt from seating in the sheave groove.

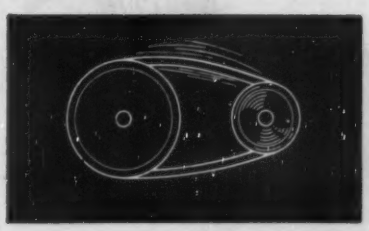
Back-side idlers



Cracks will appear on the under side of the belt, since back-side idlers force the belt to flex in a direction contrary to its construction. Use of spring-loaded back-side idlers may result in belt-snapping.

Where back-side idlers are used to provide tension take-up, they must never be smaller than the smallest pulley in the drive. Dayton V-Belts used in this case employ tension or stretchy type materials in the compression section and have a relocated neutral axis.

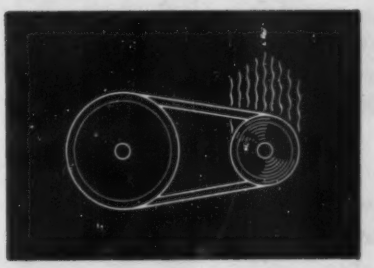
Excessive shock



Excessive shock can cause the belt to snap as well as promote bearing troubles and sheave misalignment.

Belts subject to excessive shock or heavy pulsation require strength band constructions which offer changeable ratios between stress and strain without taking a permanent stretch. Belts with soft cross sections – that will ride up and down in the groove – work well under shock as do wide angle belts. Any of these belts are available from Dayton.

Using as a clutch



V-Belts are ordinarily designed for constant loads and will burn when used as a clutch.

But, belts especially designed for use as a clutch will readily slip when a load is suddenly applied or released. Dayton cover stocks used here have a low coefficient of friction and high resistance to wear.

DAYTON'S SPECIAL V-BELT ENGINEERING SERVICE

Make use of Dayton's Special V-Belt Engineering Service when you encounter any of these designs. Your Dayton V-Belt design engineer is an expert who has devoted himself exclusively to V-Belt Drives. Your design may permit a minor modification which would adapt it to the use of low-cost standard V-Belts. Other standard Dayton V-Belts available for special applications are the Double-Angle V-Belt, the Double Cog-Belt, the Variable Speed Cog-Belt and the back-side idler V-Belt.

With one of the finest research and development laboratories in the industry, Dayton research engineers constantly advance V-Belt knowledge. They develop basic theory, prove the characteristics of the newest compositions and materials available to the rubber industry and test the performance of theoretical constructions. All of this acquired information is at your call when you need a special V-Belt.

Now, while your design is on the drawing board, is the time to call your Dayton V-Belt design engineer. He'll help you select the V-Belt which is tailored to your specific drive. The result – a compact, versatile design which meets all your minimum design requirements and one that will give its users years of trouble-free service.

Industrial Sales Engineers in Atlanta, Chicago, Cleveland, Davenport, Dayton, New York, San Francisco and St. Louis.

Dayton Rubber

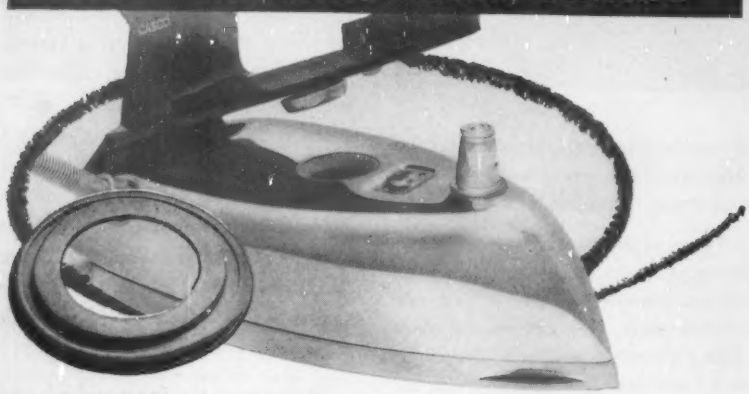
THE DAYTON RUBBER CO., INDUSTRIAL O.E.M. DIV., DAYTON 1, OHIO
WORLD'S LARGEST MANUFACTURER OF V-BELTS

If you haven't received your copy of Dayton's authoritative Handbook of V-Belt Drive Design and Selection, write for it now. Just give us your name, title, and the address of your firm.

Circle 501 on page 19

THE SHAPE OF THINGS IN MOLDED SILICONE

MOLDED SILICONE SEAL
KEEPS TAP WATER UNDER CONTROL



APPLICATION:
Funnel seal for steam and dry iron.

PROBLEM:
When this part was originally designed, Silicone rubber compounds with low shrinkage characteristics were not available. This resulted in a twofold problem; first, to produce a compound that would have excellent resistance to all types of tap water and would retain its sealing properties even if the iron were inadvertently run dry; secondly, to construct or match tooling to the characteristics of the compound.

SOLUTION:
The Acushnet laboratory chemists and tool designers working cooperatively produced a Silicone compound with a specific shrinkage rate of 5% around which tooling was finally constructed. This Silicone part, successfully molded, contributed to the safety and longer service-free life of the appliance.

Five new heat resistant and three low shrinkage Silicone compounds by Acushnet are now available for consideration in your next molded part. A complete staff of chemists and engineers offer technical assistance at any stage of design.

Send for new Acushnet Silicone Brochure

Acushnet

ACUSHNET PROCESS COMPANY
NEW BEDFORD MASSACHUSETTS

... *Precision Molded* RUBBER, SILICONES - "APCOTITE" BONDING
Address all communications to 762 Belleville Ave., New Bedford, Mass.

New Parts

(*Continued from Page* 181)

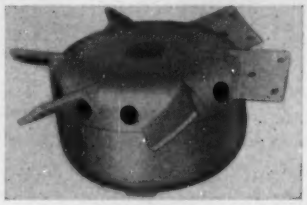
of the actuator can be altered to suit specific performance and space envelope requirements. **Ex-Cell-O Corp.,** Aircraft Div., 1200 Oakman Blvd., Detroit 32, Mich.

Circle 725 on page 19

Fan Motors

are compact units with ratings from 1/12 to 1/3-hp

Three reduced-depth direct-drive fan motors for remote condenser and central air conditioning systems have reduced-speed operation, providing quiet, vibration-free per-



formance. Speeds are 950, 775, and 625 rpm. Designed for vertical or horizontal operation, units have aluminum pressure-type blades, single-point mounting components and a thermal protection device. Power ratings are 1/12 to 1/3-hp; input is 230 v. Axial lengths are 4 to 5 in. **Electric Motors and Specialties Inc.,** 105 King St., Garrett, Ind.

Circle 726 on page 19

Self-Sealing Screws

provide vibration-resistant high-pressure seal

Seelskrews provide a combination of sealing and locking, even under vibration. One-piece units are for applications where dust, moisture, vapor or similar contaminants must be kept out. An O-ring is pressed into a groove under fas-

tener head. Tightening the screw compresses the O-ring to achieve vibration resistance and high-pressure sealing. Appearance is identi-

Circle 502 on page 19

Always, at SKF, you will receive unbiased advice

because

– All four basic types of anti-friction bearings are available from **SKF**.

because

– They offer an extraordinarily wide range of sizes and combinations to meet virtually any requirement.

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– Their long experience in the widest variety of bearing applications is your assurance of receiving sound recommendations.

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– Thousands of manufacturers have been using the **SKF** Bearing Advisory Service for many years – always with good results. This dependable service is available to you, too. 7784

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EVERY TYPE—EVERY USE

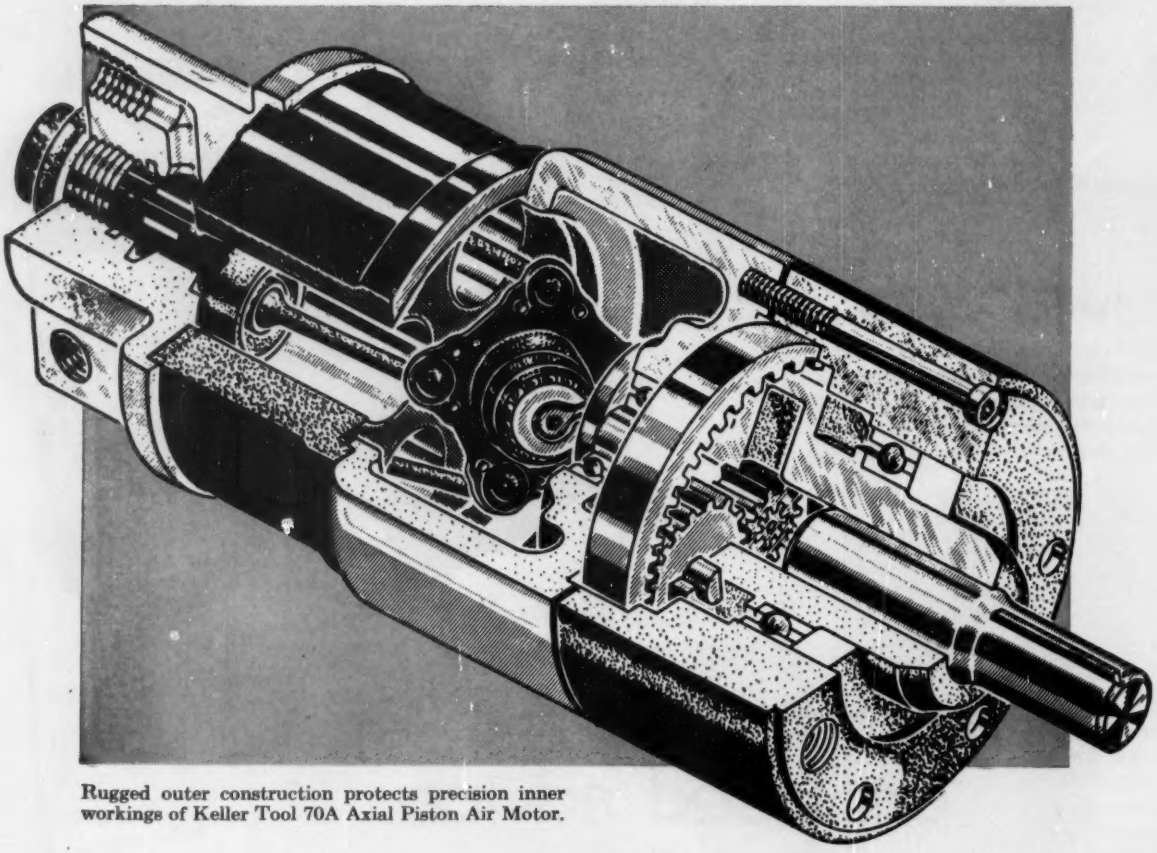
- *Ball Bearings*
- *Cylindrical Roller Bearings*
- *Spherical Roller Bearings*
- *Tapered Roller Bearings ("Tyson")*

*Reg. U.S. Pat. Off. Tyson Bearing Corporation

SKF INDUSTRIES, INC., PHILADELPHIA 32, PA.

Circle 503 on page 19

Gardner-Denver . . . Serving the World's Basic Industries



Rugged outer construction protects precision inner workings of Keller Tool 70A Axial Piston Air Motor.

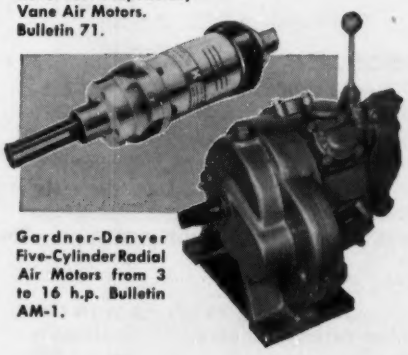
Inside information tells why Keller Tool air motor stars on tough assignments

Compact Design—Axial piston motor provides high torque and horsepower characteristics within compact dimensions.
No external spindle support needed—Generous size ball bearings safely accommodate heavy overhung load on spindle.
Face mounting—Three tapped holes assure positive mount without strapping. You position air connections for clean piping design.
Defy dust and corrosion—Enclosed construction permits use in contaminated environment. Motor withstands exposure to heat.
Operating characteristics—Instantaneous starts and stops . . . infinitely variable speed in either direction . . . non-sparking . . . cannot burn out when stalled . . . high torque at low speed . . . consistent stall torque, variable through air pressure regulation . . . efficient operation at high or low air pressure.

Send for Bulletin 70 today! It gives detailed specifications, dimensions and performance charts on 12 models of the Keller Tool Axial Piston Air Motor ranging from 0.6 to 2.7 h.p.

Other air motor favorites . . .

Keller Tool 1 h.p. Rotary Vane Air Motors. Bulletin 71.



Gardner-Denver Five-Cylinder Radial Air Motors from 3 to 16 h.p. Bulletin AM-1.

GARDNER - DENVER

KELLER TOOL division, Grand Haven, Michigan

THE QUALITY LEADER IN COMPRESSORS, PUMPS, ROCK DRILLS AND AIR TOOLS FOR CONSTRUCTION, MINING, PETROLEUM AND GENERAL INDUSTRY

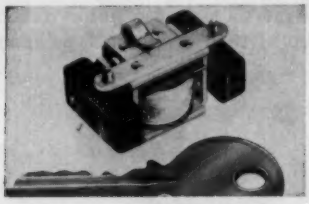
cal with conventional screws, and seal is maintained after frequent removals from equipment. Sealing material in the O-ring offers excellent resistance to petroleum or petrochemical products, and remains effective at elevated temperatures or when exposed to weathering, salt water or sunlight. The screws are recommended for application in marine, air conditioning and refrigeration, food and chemical, portable tool and home appliance fields. Wide range of standard and special sizes and threads is available. **Automatic & Precision Mfg. Co.**, 252 Hawthorne Ave., Yonkers, N. Y.

Circle 727 on page 19

Miniature Sensing Relays

withstand vibration of 10 to 200 cps at 20 g

Precision sensing relays for aircraft-component applications use snap-action switches. Units provide accurate voltage sensing with controlled differential between op-



erate and release voltages. Relays are designed and built to customer specifications. Temperature ranges include −55 to 160 F. Typical resistance to vibration is 10 to 200 cps, 10 *g;* typical shock resistance is 30 *g*. **Cook Electric Co.**, Diaphlex Div., 2700 Southport Ave., Chicago 14, Ill.

Circle 728 on page 19

Ceramic Magnet Material

provides broad energy-product maximum

Indox V is an orientated ceramic ferrite-magnetic permanent-magnet material that is orientated in the direction of pressing. Material produces peak energy product of 3.5 x 10^6, as compared to 1.0 x 10^6 for Indox I, a nonorientated material. Material is lightweight, 0.181 lb per cu in. Properties in-

Best low-cost way to incorporate variable-speed into machine designs

Choose from 8 sizes . . . ⅛ to 15 hp . . . 1.75:1 to 4:1 speed ratio. Converts any standard constant-speed motor into variable speed drive.
MAXIMUM TO MINIMUM OUTPUT SPEED POSITIONS

REEVES®

Vari-Speed Motor Pulley

Specify this easy, economical way to efficient and versatile use of the machines you design. REEVES-equipped machines adjust immediately to a variety of production speeds, production processes . . . you substantially reduce design and capacity obsolescence.

Your REEVES representative will be glad to work with you on the application best suited to your design. Offices in principal cities—or write direct for Catalog H28a-V545.

REEVES PULLEY COMPANY

Division of **RELIANCE** ELECTRIC AND ENGINEERING CO.

Columbus, Indiana

Circle 505 on page 19

IT PAYS TO HAVE
HUBBELL
GOOD CONNECTIONS
REG. U.S. PAT. OFF.
Series BB Relay . . . Nerve Center of Stromberg-Carlson Industrial Control Systems

SECURED with HUBBELL

HIGH TENSILE STRENGTH STAINLESS STEEL MACHINE SCREWS

Nerve center of many Stromberg-Carlson industrial controls is the multi-contact relay above, each contact spring and insulator of which is carefully sandwiched together and compressed under high pressure, ready for insertion of the binding screws. In order for the relay to operate satisfactorily the binding screws must maintain these high pressures so that the contact springs cannot and will not twist, loosen and shift position.

Ordinary machine screws just couldn't "stand the gaff". They stretched and broke under the strain, thereby causing endless production and maintenance headaches. Only after Stromberg engineers had set a rigid performance standard could the solution be found. Hubbell high tensile stainless steel machine screws made to Stromberg-Carlson specifications, proved to be the answer.

Lowest Cost To Service

Quite obviously, better materials and components add to the initial cost of any product. But how about the long term cost? When a product assembles quickly and easily, performs satisfactorily and requires a minimum of maintenance, the initial "extra" cost is quickly offset. Are you putting this time-tested principle into practice? Start today by specifying Hubbell quality fasteners.

Prices and delivery on request. Simply send blueprint or sample of the item.

HARVEY HUBBELL, INC.

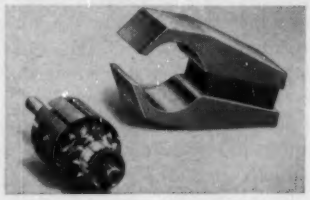
HIGHEST QUALITY
WIRING DEVICES • MACHINE SCREWS

OVER 60 YEARS' EXPERIENCE in the manufacture of highest quality, rolled thread machine screws and special cold headed parts.

MACHINE SCREW DEPARTMENT BRIDGEPORT 2, CONNECTICUT

New Parts

clude a coercive force H_c of 2000 Oersteds, residual induction B_r of 3840 Gausses, and at peak energy output, B_d is 1920 Gausses and H_d is 1820. New material provides a



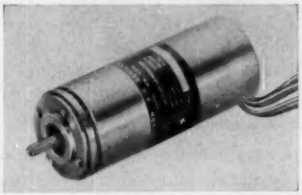
wider high-efficiency operating range than those previously available because energy product has a broad rather than a narrow maximum. **Indiana Steel Products Co.**, 700 Valparaiso St. W., Valparaiso, Ind.

Circle 729 on page 19

Tachometer-Generator

for servomotors has linearity of ±½ per cent

Servomotor tachometer generator features ±0.5 per cent linearity. Unit consists of a high-performance low-inertia ac servomotor directly coupled to a drag-cup type induc-



tion generator. Unit functions at temperatures to 150 C and is suitable for applications in instrumentation, fire control, autopilots, missiles and computers. Low null is 0.008 v rms in phase, 0.015 v rms quadrature, and 0.019 v rms total null. Linearity is 0.5 per cent at 3600 rpm. **Eastern Air Devices Inc.**, 385 Central Ave., Dover, N.H.

Circle 730 on page 19

Solenoid Valve

controls steam, fluids or gases to 400 F

Two-way packless solenoid valve has a variety of applications for the automatic control of steam, hot fluids or gases to 400 F. Internal pilot-operated solenoid valve

Circle 506 on page 19

NOTHING *can equal Stainless Steel*

in its unique combination of properties

No other design material can match Stainless Steel in its combination of desirable properties: corrosion resistance, strength, hardness, beauty, cleanability and easy fabrication. For a reliable source of supply, United States Steel offers you the widest range of types, finishes and sizes.

UNITED STATES STEEL CORPORATION, PITTSBURGH
AMERICAN STEEL & WIRE DIVISION, CLEVELAND
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
NATIONAL TUBE DIVISION, PITTSBURGH
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS STAINLESS STEEL

SHEETS • STRIP • PLATES • BARS • BILLETS
PIPE • TUBES • WIRE • SPECIAL SECTIONS

USS

UNITED STATES STEEL

For Sanitation

Food juices are incredibly corrosive, so some restaurants have a lot of trouble in their cold storage rooms because the racks corrode and harbor bacteria. Eastern Steel Rack Company makes racks from Stainless Steel. They are easy to keep clean; and, for all practical purposes, they *never* wear out.

For Corrosion Resistance

This petrochemical extract fractionator was originally made from carbon steel . . . but corrosion ate through the plates and put it out of service in *just two months*. They lined the tower with type 316 Stainless Steel. When examined, the tower had been in service 21 months, and the Stainless was still in good condition.

For Cleanliness

Hawthorne Paper Company, Kalamazoo, Mich., goes to extraordinary lengths to guard against color contamination. Old wooden tanks were thrown out and replaced with Stainless Steel. According to the men at Hawthorne, the Stainless has absolutely no contaminating effect, and it's easy to fabricate.

Circle 507 on page 19

VALLEY BALL BEARING **MOTORS**

Custom Built . . .
NOT Custom Priced!

AIR COOLED

- POLYPHASE, 50 OR 60 CYCLES
- SQUIRREL CAGE INDUCTION
- HIGH TORQUE
- ½ TO 75 H.P.

Cool Running . . . Continuous Service . . .

that's the axiom Valley Motors live up to.

They have been tested and proven in every industry where dependable service and power is a requirement. Remember they are semi-enclosed to assure protection against dripping or splashing liquids, metal chips and abrasive dust.

WRITE FOR COMPLETE INFORMATION

VALLEY
ELECTRIC CORPORATION
4221 Forest Park Blvd. • St. Louis 8, Mo.

Circle 508 on page 19

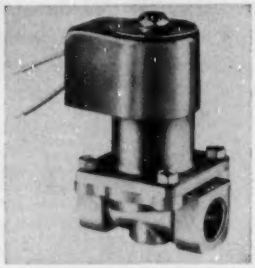
Our new handy catalog gives you finger tip information on the type, model, H.P. and G.P.M. of the Gusher Pump that best fits your application. Write for it today—

THE RUTHMAN MACHINERY CO.
1811 Reading Road **Cincinnati, Ohio**

Circle 509 on page 19

New Parts

has a forged brass body and bonnet. Teflon disks provide tight shut-off without maintenance problems. Internal operating parts are designed to last the life of the



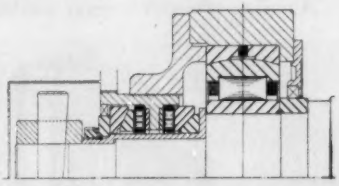
valve. The valve has low power consumption and is supplied for normally closed operation. It is equipped with NEMA 1 pressed-steel enclosures which can be rotated 360 deg for mounting in any position. **Automatic Switch Co.**, 391 Lakeside Ave., Orange, N. J.

Circle 731 on page 19

Thrust Bearing

has thrust capacity of 114,275 lb at 100 rpm

Double-acting aligning thrust bearing, Type DAT, is designed for use where potential misalignment and



heavy but intermittent thrust loads from either direction are present. Staggered rollers provide even wear distribution. Bearing thrust capacity at 100 rpm is 114,275 lb. Bearing capacity, size and design can be modified to customer specifications. **Rollway Bearing Co.**, 541 Seymour St., Syracuse, N. Y.

Circle 732 on page 19

Anchor Nut

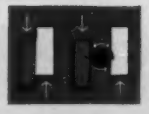
has thread-relief design

Kaylock K1000 all-metal self-locking anchor nut is lightweight and has a thread-relief design. It permits the use of short-thread bolts for saving in weight. Thread-relief design allows bolt grip to enter

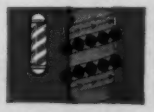
SAGINAW b/b SCREWS are guaranteed 90% EFFICIENT!

Require 4/5 LESS torque than Acme Screws for same linear output on Actuator and Positioner Applications! Saves space, weight!

WHAT IT IS AND HOW IT WORKS



Let's start at the beginning, with the familiar principle that there's far less friction in *rolling* than in *sliding*. By applying this principle,



Like stripes on a barber pole, the balls travel toward end of nut through spiral "tunnel" formed by concave threads in both screw and mating nut.

the *Saginaw ball/bearing Screw* radically increases the efficiency of rotary-to-linear motion (and vice versa). Instead of *sliding*, mating surfaces *glide* on rolling steel balls.

At end of trip, one or more tubular guides lead balls diagonally back across outside of nut to starting point, forming closed circuit through which balls recirculate.

SIX DESIGN ADVANTAGES

1. **Vital Power Savings.** Permit much smaller motors with far less drain on electrical system, simpler circuitry.

2. **Space/Weight Savings.** Screws themselves are smaller, lighter; permit smaller motors and gear boxes; eliminate auxiliary equipment required by hydraulics.

3. **Precise Positioning.** Machine-ground type will position components far more precisely than hydraulics or pneumatics; tolerances on position are held within .0006 in./ft. of travel.

4. **Temperature Tolerance.** Normal operating range from —75° to +275° F.; in selected materials, will function efficiently as high as +900° F.

5. **Lubrication Latitude.** If lube fails, will still function with remarkable efficiency. Units have been built and qualified for operation without lubrication.

6. **Fail-Safe Performance.** Far less vulnerable than hydraulics; Gothic-arch grooves, yoke deflectors and multiple circuits provide added assurance against failure.

SAGINAW b/b SPLINE

Utilizing the same basic *gliding ball* principle, Saginaw has developed the *Saginaw b/b Spline* which radically increases the efficiency of transmitting or restraining high torque loads.

Averages 40 times lower friction coefficient than sliding splines!

It can be fitted with integral gears, clutch dogs, bearing and sprocket seats, etc., for use with a wide variety of electrical units. Units have been built from 3 inches to 10 feet long—⅜ to 6 inches in diameter.

Available in custom machine-ground and stock rolled-thread types. Units have been built from 1½ inches to 39½ feet long—⅜ to 10 inches in diameter.

Saginaw ball bearing Screws & Splines

SAGINAW STEERING GEAR DIV., GENERAL MOTORS CORP., SAGINAW, MICH.

SEND COUPON FOR NEW 1957 ENGINEERING DATA BOOK

Saginaw Steering Gear Division, General Motors Corp.
b/b Screw and Spline Operation
Dept. 6H, Saginaw, Michigan

Please send new engineering data book on Saginaw b/b Screws and Splines to:

NAME_____

COMPANY_____ TITLE_____

ADDRESS_____

CITY_____ ZONE____ STATE_____

CLUTCHES FOR POWER CONTROLS DESIGNS

THE NEW HILLIARD-TWIFLEX

Centrifugal Coupling

1 AUTOMATIC smooth starting with protection against overload shock.

2 FLEXIBLE in all directions without any loose joints.

3 ADJUSTABLE to exactly suit the operating conditions.

4 SIMPLE CONSTRUCTION and easy assembly even in blind installations.

Hilliard-Twiflex Centrifugal Couplings provide automatic shockless power transmission and trouble-free operation even under relatively great misalignment without any lubrication whatsoever.

They are being used very successfully in the drive of compressors—agricultural sprayers—mixers—conveyors—generators—fans and blowers—pumps—hammer mills—crushers—winches and hoists—refrigeration equipment—textile machinery—and wherever smooth, efficient operation is needed.

Tests in a variety of installations for over five years prove the Twiflex is the practical solution to many drive problems.

WRITE TODAY FOR BULLETIN CE-3 WITH COMPLETE INFORMATION.

★

• OTHER HILLIARD CLUTCHES •

SINGLE REVOLUTION CLUTCHES for automatic accurate control—electrical or mechanical—of intermittent motion, indexing, cycling and cut-off. Ask for Bulletin 239.

OVER-RUNNING CLUTCHES for automatic instantaneous engagement and release on two speed drives, dual drives and ratchet or backstop action. Ask for Bulletin 231.

SLIP CLUTCHES for overload protection, or constant torque and to provide constant tension and permit speed variation on rewind stands. Ask for Bulletin 300.

★ CONSIDER AUTOMATION-INVESTIGATE THESE PRODUCTS

THE HILLIARD Corporation

MANUFACTURING CLUTCHES FOR OVER 50 YEARS

103 West Fourth St.
Elmira, New York

IN CANADA: UPTON • BRADEEN • JAMES, LTD.

New Parts

base of the nut, reducing need for shims and changes in bolt-grip lengths. Elliptical locking device assures positive self-locking action under severe vibration. Locking device plus heat-treated threads permit repeated insertions and re-

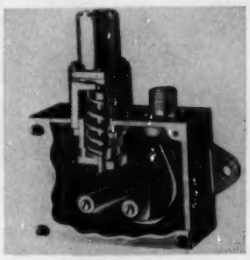
movals of mating screws without loss of locking ability. Carbon steel nut is approved for use in temperatures to 550 F; for higher temperature or nonmagnetic applications nuts of A286 corrosion-resistant steel are provided. Available in sizes from 8-32 through ⅜-24, the nut is precision made in accordance with applicable military specifications. **Kaynar Co.**, Box 2001, Terminal Annex, Los Angeles 54, Calif.

Circle 733 on page 19

Pressure Switch

operates from zero to 1200 psi

Hydraulic and pneumatic pressure switch operates from 0 to 1200 psi and withstands over pressure as high as 3000 psi without distorting pressure element. Switch is adjust-



able over its entire pressure range, and adjustments can be made without interfering with the pressure element. Made of cast-aluminum alloy, the entire unit is totally enclosed and weatherproof. It uses any Micro switch, 15 amp, 120 to 460 v, ac, with single-pole, double-throw silver contacts. Switch can be arranged for wall or bracket mounting in any position. It is also available with stainless steel construction, and for dc

(Advertisement)

CORNING GLASS BULLETIN

FOR PRODUCT DESIGNERS

Practical pampering

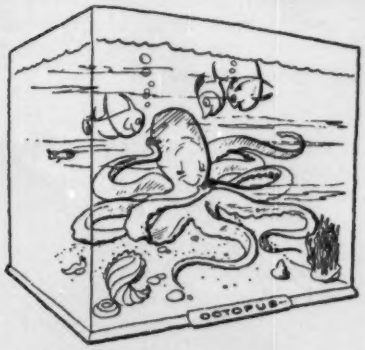
At Marineland of the Pacific, Palos Verdes, California, you'll find a tank of contented, though captive, cephalopods.

But life was not always rosy for these octopuses. (Cephalopod is the order to which octopuses belong.)

Time was when the aquatic zoo keepers at Marineland were octopus-deep in trouble. It began with trying to provide water cooled to the same temperature as the natural environment of an octopus.

Turned out that the heat-exchanger system left copper pickup in the cooled water. And copper is death to octopuses. A concentration of 0.04 parts per million will snuff out the life of an octopus in about two hours. With the going price of about $100 the head, that's a lot of money if you let copper stay in the plumbing.

But the octopuses now happily cavort the day long in water that's cool and pure. The answer—three Corning Glass Works PYREX brand Shell and Tube Heat Exchangers.



O.K., you don't own (or intend to acquire) a pet octopus that needs pampering. Still, there's considerable to be learned from a practical standpoint. To wit—there might be a PYREX brand glass that will answer that knotty problem you're working on right now.

Take contamination, for instance. For most purposes, glass is inert—it just won't mix with, add to, or detract from what you put *in* or *around* it. In the case of PYREX brand glass No. 7740 this aloofness applies to most acids and alkalies, as well as steam under pressure.

Then, too, this glass handles thermal changes with what might be termed indifference since it has a linear coefficient of expansion of 32 x 10^{-7} between 0 and 300° C.

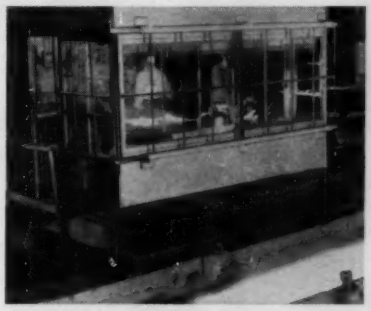
You'll also find that this glass is rugged, readily workable, and available in a wide variety of economical forms.

Suggestion: Put all kinds of useful facts about glass and glass applications at your fingertips. Send for free copies of B-83, "Properties of Selected Commercial Glasses"; and B-84, "Manufacture and Design of Commercial Glassware."

Or, spell out exactly what you need in terms of your problem and let us see if we can't come up with a *glass answer.*

Helping hand in "hot spots"

That's a *glass* shield you see in front of the steel mill shear pulpit operators in the picture.



The glass is a PYREX brand infrared reflecting type. It's heat-resistant, chemically stable and coated on one side with a thin, transparent film of metallic oxide.

Installed with the coated side facing the heat source, it reduces temperature behind the glass 34° F. Yet, operations are still kept under visual observation since this glass transmits about 75% of the visible spectrum.

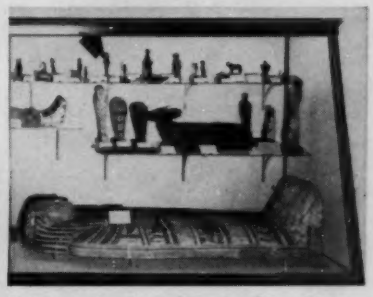
This glass application is just one of the many that may interest men in your shops. They may also have need for such items as fume duct windows, sight glasses, and chemical-resistant surfaces.

Details on all these (along with facts about blue observation glass and the astounding VYCOR brand glass No. 7900) are summed up in the revised version of our Bulletin PE-34. Get a free copy and be set to lend a helping hand in "hot spots."

How to keep a mummy dry

Dampness is no laughing matter to museum keepers—or for that matter for makers (and users) of TV sets, pianos, and such.

That's why Dampp-Chaser, Inc., is in business. They make an ingenious item called, quite logically, Dampp-Chaser.



Behind the top frame (see arrow) is a Dampp-Chaser to keep rare museum pieces dry. Glass tubing by Corning helps in this unusual assignment.

The damp gets chased by a heating element; the heating element is inside glass tubing; the glass tubing is inside an aluminum tube.

We make the glass tubing. Dampp-Chaser, Inc., buys it because it makes a fine insulator, provides protection against leakage, plus an important safety factor in case of accidental over-loading of the circuit. To this we add—glass tubing by Corning is also economical and readily available, no small considerations in the profit picture.

During the past ten years, Dampp-Chasers have rolled up some 6-billion hours of protection against dampness. Glass helped make this a trouble-free record.

Offer: Two booklets to show you the varied ways in which glass is being put to use. "Glass and You" is a sweeping survey that even the people in the front office will appreciate. And for your own files, Bulletin IZ-1, "Glass . . . its increasing importance in product design."

Corning means research in Glass

CORNING GLASS WORKS, 52-2 Crystal Street, Corning, N.Y.

Please send me the following material: Illustrated booklet, "Glass and You" ☐; Bulletin IZ-1, "Glass . . . its increasing importance in product design" ☐; Bulletin B-83, "Properties of Selected Commercial Glasses" ☐; Bulletin B-84, "Manufacture and Design of Commercial Glassware" ☐; Bulletin PE-34, "Corning Flat Glasses" ☐.

Name_____ Title_____

Company_____

Street_____

City_____ Zone_____ State_____

Circle 512 on page 19

MEMORANDUM
FROM ENGINEERING DEPARTMENT
12/12/55
Design Group
Att.: C. D. Smith
Vibrating Conveyor #3 broke down after approximately
17,000,000 cycles of operation. Spring return lever
failed, due to low fatigue resistance. Flexloc locknuts
were, but still locked in original positions.
Recommendations:
1) Redesign lever to give increased strength in
center section.
2) Eliminate side play in lever motion which has
been causing excessive wear in related parts.
3) Continue use of Flexloc locknuts.
B.F.W.

Why designers specify FLEXLOC self-locking nuts

Where products must be tough . . . must stand up under vibration, shock and abuse . . . designers specify rugged, reliable, precision-built FLEXLOC self-locking nuts as fasteners.

HERE'S WHY:

FLEXLOC locknuts are strong: tensile strengths far exceed accepted standards. They are uniform: carefully manufactured to assure accurate, lasting spring tension in the flexible locking collars. And they are reusable: rough screw threads, repeated removal and replacement, frequent adjustments will not affect their locking life.

Standard FLEXLOC self-locking locknuts are available in a wide range of standard sizes and materials, to meet the most critical locknut requirements. Your authorized industrial distributor stocks them. Write us for complete catalog and technical data. Flexloc Locknut Division, STANDARD PRESSED STEEL CO., Jenkintown 18, Pa.

FLEXLOC® LOCKNUT DIVISION

STANDARD PRESSED STEEL CO.

SPS

JENKINTOWN PENNSYLVANIA

Circle 513 on page 19

application. **Alloy Bellows Engineering Co.**, 18125 Roseland Rd., Cleveland 12, O.

Circle 734 on page 19

Thin-Wall Tubing

is available in lengths to 200 ft

New process for forming and welding of very light-gage tubes from high-tensile cold rolled alloy strip provides continuous lengths to 200 ft, better mechanical properties for corresponding metal thicknesses and diameters, and lower cost than seamless drawn tubes of equivalent sizes. Tubing is available in stainless steel, carbon steel, titanium, brass, bronze, and other weldable alloys. Size range is from ¼-in. OD by 0.005-in. wall to 1¼ OD by 0.015-in. wall. Stainless steel tubing (type 321 or 347) conforms to specification MIL-T-6737A for aircraft pneumatic use, high pressures, temperatures to 1500 F, and corrosive conditions. **Universal Tube Corp.**, 2133 S. Kedzie Ave., Chicago 23, Ill.

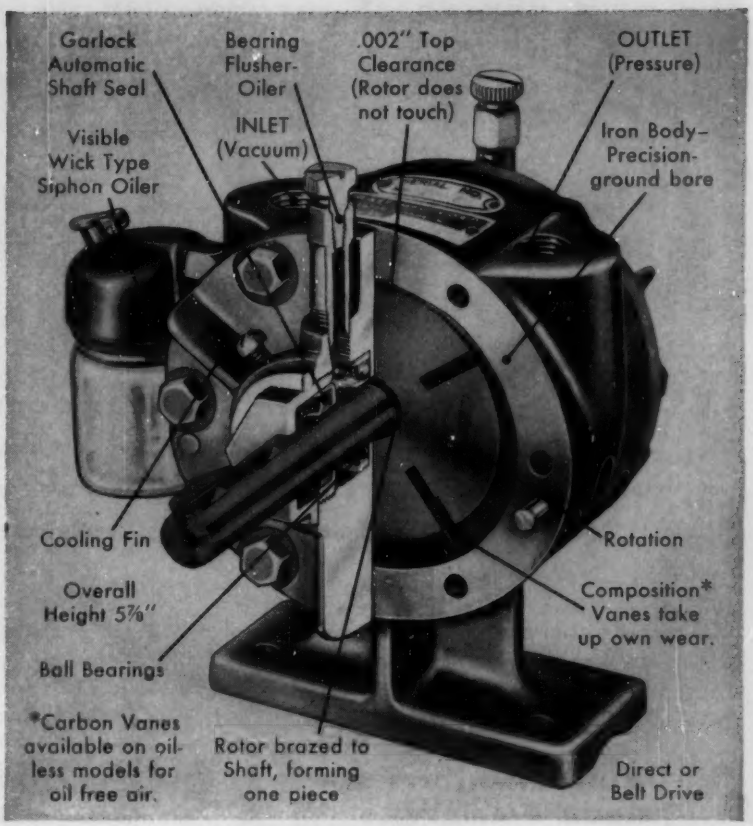
Circle 735 on page 19

Stepping Synchro

operates in increments of 1 deg

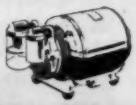
Model 89161A-1 stepping synchro utilizes an electromechanical positioner to drive the rotor of a differential synchro in fixed increments of 1 deg. It produces an ac output that is synchronous with rotor position. Rotation of the mechanism is unlimited in both directions, and is produced by an electrical input pulse at any speed up to 60 deg per second. The synchro fits many applications such as found in complex directional or guidance systems where servo actuation in precise increments of

(*Continued on Page* 198)

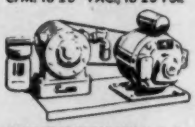

Garlock Automatic Shaft Seal
Bearing Flusher-Oiler
.002" Top Clearance (Rotor does not touch)
OUTLET (Pressure)
Visible Wick Type Siphon Oiler
INLET (Vacuum)
Iron Body–Precision-ground bore
Cooling Fin
Rotation
Overall Height 5⅞"
Composition* Vanes take up own wear.
Ball Bearings
*Carbon Vanes available on oil-less models for oil free air.
Rotor brazed to Shaft, forming one piece
Direct or Belt Drive

Rotary Vane

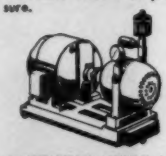
Quality and simplicity keep GAST AIR PUMPS operating for years at high efficiency levels



INTEGRAL-MOTOR PUMPS 1/12 to 1/3 H.P. .6 to 4 CFM. to 28" VAC. to 25 PSI.



LIGHT-DUTY PUMPS, V-belt or direct drive. 2 to 24 CFM. Moderate vacuum or pressure.



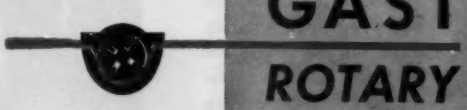
HEAVY-DUTY PUMPS, 1/4 to 1-1/2 H.P. 4 to 21 CFM. To 28" VAC. or 30 PSI. Cooling fans and fins.

As original components—or for special plant use—Gast Air Pumps offer important advantages. This cutaway reveals many reasons why they are specified as "original equipment" by more and more leading manufacturers.

All models are built to high quality-precision standards in a new, modern plant. All embody this inherently efficient, simple rotary-vane design. Balanced rotor is free of vibration. Sliding vanes are light in weight—for minimum motion-energy-friction loss compared to other pump designs. As vanes take up their own wear automatically, pump delivers full performance through years of use.

Get full details—write for "*Application Ideas*" *Booklet and Catalog*. Many sizes—*mention capacity and type that interests you!* **Gast Manufacturing Corp.**, P. O. Box 117-P, Benton Harbor, Michigan.

Original Equipment Manufacturers for Over 25 Years



GAST ROTARY

- AIR MOTORS TO 4 H.P.
- COMPRESSORS TO 30 P.S.I.
- VACUUM PUMPS TO 28 IN.

SEE OUR CATALOG IN SWEET'S PRODUCT DESIGN FILE

Circle 514 on page 19

ONE OF A SERIES OF INFORMATIVE MESSAGES FROM HYATT . . .

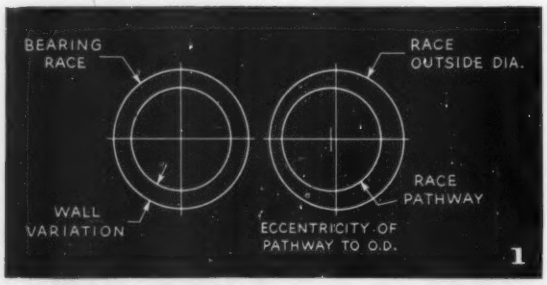
The Inside Secrets of Smoother Performance

How HYATT quality controls assure race concentricity, roller diameter uniformity and other internal essentials of smoother, longer-lived cylindrical roller bearings . . .

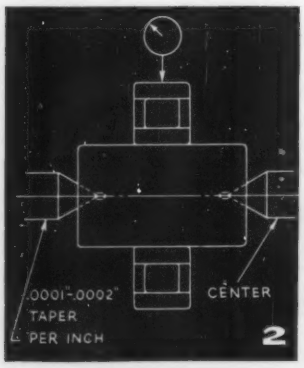
The running accuracy and smoothness of a roller bearing is governed primarily by its internal dimensions and clearances. The most important of these are:

1. CONCENTRICITY OF RACE DIAMETERS

Eccentricity of race diameters is usually interpreted in terms of *wall variation*, Figure 1, on the individual components and in terms of *radial run-out* on the assembled bearing. The



assembled bearing is usually mounted on an arbor, Figure 2, having a slight taper (.0001″ to .0002″ on the diameter per inch of length) and the radial run-out indicated as shown. The radial run-out is the difference between the minimum and maximum readings obtained when rotating the outer race one revolution with the arbor stationary for outer race radial run-out, or rotating the arbor one revolution with the outer race stationary for inner race radial run-out.

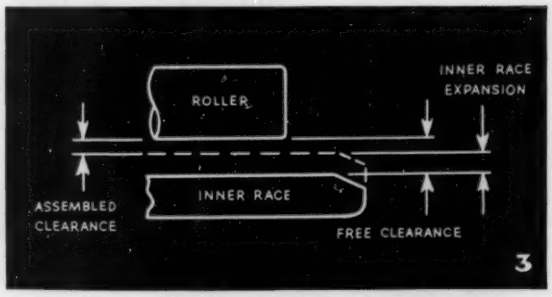


2. UNIFORMITY OF ROLLER DIAMETERS

Another factor governing running smoothness is *roller diameter uniformity*. This is usually obtained by segregating the rollers into diameter variation classes of .00005″, .0001″, or .00015″, depending on the bearing size and the nature of the application, and assembling only rollers of the same group into a given bearing. Gauging for this segregation necessarily rejects excessive taper.

Uniformity of roller diameters is important for another purpose. It provides the user with a bearing in which the internal diametral clearance is controlled within the closest possible limits. The rollers are matched with races which are segregated for pathway size in a fashion similar to the rollers, usually to twice the diameter limits of the rollers. The internal clearance can thus be manipulated at will by combining various diameter classes of races and rollers; but once a particular range is selected, it will remain constant within the combined limits of the roller and race pathway diameter limits. Here, again, a tapered condition of the race pathway is automatically rejected.

Obviously, the internal clearances of commercial bearings must be standardized for the practical reasons of cost and availability, but the clearance values have been so selected that under the specified fits the *running* clearance is at the most desirable minimum, depending on bearing type and size. Figure 3 (magnified).

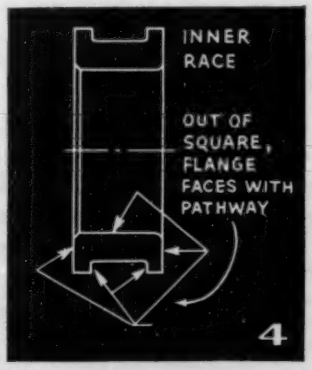


Checking wall variation, flange run-out and race end squareness on combination gauge.

3. SQUARENESS OF ROLLER ENDS AND FLANGE FACES

One other tolerance that contributes to the running efficiency of HYATT Hy-Load Series Bearings of the flanged race type is the *squareness of roller ends with roller diameters* and the *squareness of flange faces with the race pathways.*

Flanged race bearings are commonly used for locating shafts laterally and for running conditions of light and intermittent thrust load. For best operating results, the ends of the rollers must be flat and square with the diameter within a matter of tenths. The lateral clearance between the roller and the race shoulders must also be held to a minimum. This means close tolerances on roller length and race pathway width, and the flange face, Figure 4, must be square with the roller pathway. When all these conditions are satisfied, there will be no tendency for the rollers to skew and raise the operating temperature of the bearing, nor will there be any unusual force on the separator or cage with a tendency toward wracking and noisy operation.



The *side run-out* of the individual races or the *out-of-square* of the ends with the fitting diameters is also important, especially in applications where a number of parts are held together endwise and where the pressure might be sufficient to tilt the race, creating a condition of excessive taper on the roller pathway with consequent roller skewing and the development of excessive heat and noise.

All these internal dimensions and clearances are so carefully controlled that HYATT Hy-Roll Bearings have built an unsurpassed reputation among design engineers for exceptionally long, smooth and trouble-free performance.

YOU WILL FIND MORE DETAILS in HYATT General Catalog No. 150, or your nearby HYATT Sales Engineer will gladly help you choose the type best suited to your design requirements. Remember, HYATT is America's first and foremost maker of cylindrical roller bearings. Hyatt Bearings Division of General Motors Corporation, Harrison, New Jersey.

GM GENERAL MOTORS

HYATT HY-ROLL BEARINGS FOR MODERN INDUSTRY

Only 5 basic parts, which can be completely disassembled and reassembled in minutes with only a screw driver as your complete tool kit.

This Quality of Simplicity means...

1 Longest, Trouble-Free Operation
An absolute minimum of wearing parts. Simple, rugged construction. Sound design, with more than ample mechanical and electrical safety factors. Exclusive ball bearing solenoid linkage reduces wear — assures long, trouble-free operation.

2 Simplest to Adjust and Maintain —
The *only* brake with external, visual wear indicators. Adjustment is seldom required, due to superior friction lining materials selected for long wear and resistance to heat. When indicated, however, torque and wear adjustments can be made in seconds with a screw driver as your complete tool kit. Installation is fast, and simple. Complete brake can be disassembled in minutes without special tools.

3 Fast Stop — Quick Release
Brake is spring-set, solenoid-released without delay or drag. Sets automatically in event of power failure. Can also be manually released, returning to normal operation automatically.

4 An Enclosure — A Mounting — A Size for Every Need
Explosion-proof, dust and waterproof, or standard enclosure. Vertical or horizontal, motor frame or floor mounting. Over 150 standard sizes and types to fit NEMA motor frames from 1/20 to 100 hp size range. Stub or thru-shaft design. Any AC voltage or DC shunt or series windings. Torque range from 6 lb in. to 7,500 lb ft.

13

BRAKES MILWAUKEE Stearns WISCONSIN CLUTCHES
ELECTRIC CORPORATION
120 NORTH BROADWAY • MILWAUKEE 2, WISCONSIN

If you're interested in cutting waste time—stepping up production cycles, call your local Stearns representative for complete magnetic brake data. Or write Stearns direct for free Brake Portfolio F.

New Parts

(*Continued from Page* 195)

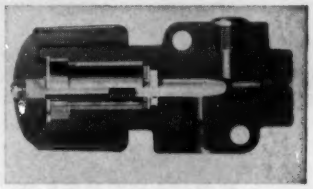
rotation is necesary. **G. M. Giannini & Co. Inc.**, 918 E. Green St., Pasadena 1, Calif.

Circle 736 on page 19

Needle Valves

are nontoxic and nonflammable

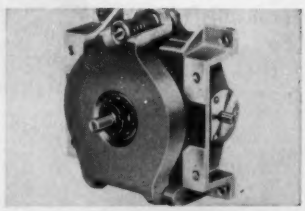
Bubble-tight needle valves are available for fluid systems where corrosion problems exist from internal, external, chemical, electrical or natural corrosive elements. Nontoxic and nonflammable, the valves are manufactured from polyvinyl chloride, Teflon, Kel-F, and 18-8 stainless steel. Calibrated body and indicator handle provides micrometer-fine adjustment. Low-friction ring seals against the Kel-F needle to produce a virtually wearproof seal for high or low pressure and vacuum. Valves are available in ⅛ and ¼-in. female pipe sizes and ⅛, ¼ and ⅜-in. OD male tube connections. Temperature range is to 170 F, 170 psi continuous duty. Two mounting bosses with clearance for ¼-in. bolts make possible a variety of mounting arrangements. **Chemtrol Corp.**, 1513 W. El Segundo Blvd., Compton, Calif.



Circle 737 on page 19

Ball and Disk Integrators

have maximum speed of 1000 rpm



Ball and disk integrators included in a standard electromechanical breadboard parts line are designed for use in computing systems re-

Circle 516 on page 19

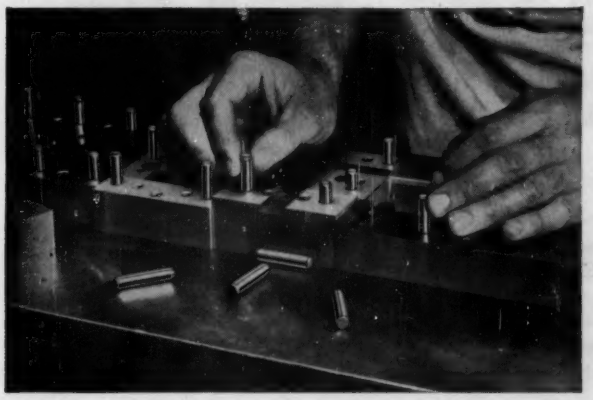
"STOCK ANSWER"
to many a design problem

ALLEN DOWEL PINS

ALLEN DOWEL PINS are being profitably employed in a thousand and one ingenious ways beyond their conventional applications in tool and die work — as economical roller bearings, as axles, precision plugs, hinges and wrist pins to name a few.

If you have an application that will utilize the great strength, accuracy and fine finish of Allen Dowel Pins, you can save substantially on the cost of your product — because you can secure them at favorable prices right from your Allen Distributor's stock.

Check the quick facts at the right and write directly to Allen's Engineering Department for further technical information.



SPECIFICATIONS

- Made from Allenoy heat treated steel. Surface hardness 62-64, Rockwell C scale; core hardness 52-54. Case depth .010" to .020" depending on size.
- Single shear strength 160,000 to 180,000 p.s.i.
- Surfaces precision ground to ± .0001" with micro-inch finish of 6 RMS max.
- Sizes: Diameters, ⅛" to 1". Lengths, ⅜" to 6".
- Two standard oversizes — .0002 for press fits between mating parts, or .001 for repair work, or holes machined oversize.

ALLEN HEAD

ALLEN
MANUFACTURING COMPANY
Hartford 2, Connecticut, U.S.A.

Circle 517 on page 19

LOVEJOY

Variable SPEED PULLEYS

SELECT-O-SPEED TRANSMISSIONS

Save You Money

HERE'S WHY:

- ECONOMICAL IN COST compared to other variable speed transmission equipment. Simple in design but rugged in construction to give you long dependable service.
- EASILY INSTALLED on new or old equipment. Just as easy to operate. Finger-tip adjustment gives the right speed instantly.
- MAINTENANCE IS NEGLIGIBLE. No complicated mechanisms to get out of order. All parts can be readily inspected. Belts can be quickly adjusted or replaced.

Lovejoy Variable Speed Pulleys

are available in a complete range of sizes from fractional to 15 hp., ratios to 3 to 1.

Shown is a typical Lovejoy countershaft unit controlling speed of automatic spring coiler.

Lovejoy Select-O-Speed Transmissions

can be supplied with hand wheel or lever control. Fractional to 5 hp., ratios to 10 to 1.

This Lovejoy Select-O-Speed is used to control the speed of a printing press.

For your variable speed application, there is a type and size Lovejoy unit that will give you initial economy, dependable performance and long service life.

GET FULL DETAILS NOW!

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LOVEJOY FLEXIBLE COUPLING CO.

4818 W. LAKE STREET • CHICAGO 44, ILLINOIS

Mfrs. of Flexible Couplings, Variable Speed Pulleys and Transmissions, Motor Bases and Universal Joints.

Circle 518 on page 19

New Parts

quiring mechanical solution of differential equations, as control or sensing elements in servo systems, or as servo-system output in rate generators. Ball carriage has 2-in. maximum travel, and recommended maximum output torque is 5 oz-in. Torque required to move ball carriage at its input shaft is 1 oz-in. Maximum disk input torque required at zero load is 3 oz-in., and maximum recommended speed of integrator is 1000 rpm. Integrator disk is hardened to Rockwell C65 and precision lapped to super finish. **Beckman-Helipot Corp.**, Newport Beach, Calif.

Circle 738 on page 19

Flexible Coupling

permits easy disassembly of connected machinery

Type RRL radially removable flexible coupling permits disconnection of two units without axial movement of the shafts. It is well suited for applications where driven equipment must be disconnected while driving unit continues to operate. There is no wear on the metal jaws of the coupling since the load is transmitted by compression of the one-piece load cushion. Power ratings range from 7.5 to 40 hp at 1800 rpm. Maximum bores range form 1⅜ to 2¼ in. with maximum OD from 2-9/16 to 5 in. Maximum overall length is from 6⅛ to 7⅝ in. **Lovejoy Flexible Coupling Co.**, 4882 W. Lake St., Chicago 44, Ill.

Circle 739 on page 19

Time-Delay Relay

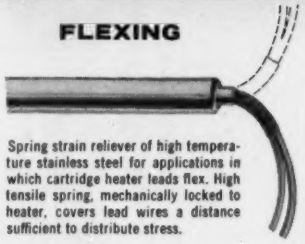
is unaffected by vibration

Electronic time-delay relay consumes as little as 1 w and requires no warm-up. Hermetically sealed unit is for equipment such as guided missiles, aircraft and similar applications. Circuit employs cold-cathode tubes that are unaffected

TAKE YOUR PICK!

Special Chromalox features solve 3 spot heating problems

FLEXING

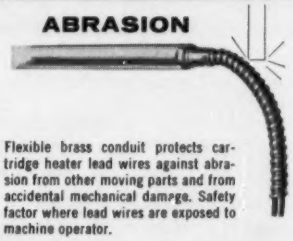


Spring strain reliever of high temperature stainless steel for applications in which cartridge heater leads flex. High tensile spring, mechanically locked to heater, covers lead wires a distance sufficient to distribute stress.

MOISTURE

Moisture-resistant flexible brass conduit protects lead wires of cartridge heaters operating in presence of steam, water, oil and vapors. Also offers added protection from flexing, vibration and mechanical damage.

ABRASION



Flexible brass conduit protects cartridge heater lead wires against abrasion from other moving parts and from accidental mechanical damage. Safety factor where lead wires are exposed to machine operator.

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Get the full story. Call your Chromalox Representative or write today for Bulletin 850.

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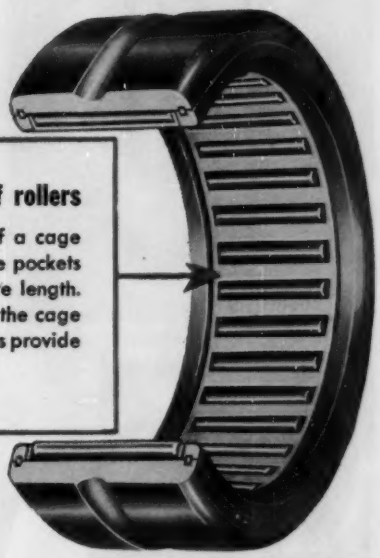
Circle 519 on page 19

ORANGE *Cage Type* NEEDLE BEARINGS

reduce friction to a minimum



HERE'S THE REASON:

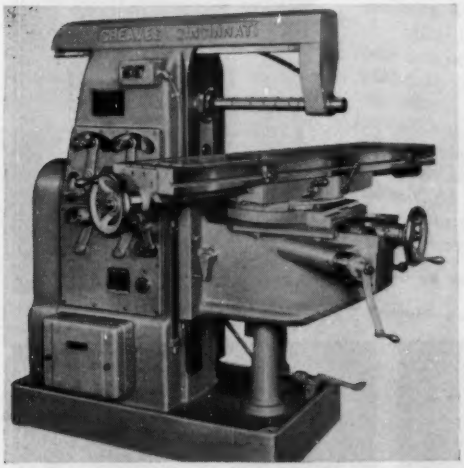
Cage assures permanent alignment of rollers

Each needle roller is retained in pockets of a cage made of anti-friction, non-ferrous metal. These pockets guide and align the rollers along their entire length. The cage does not wear on the rollers, since the cage land rides on the outer race. Square end rollers provide maximum effective roller length.

Run quieter...smoother...cooler...longer

because

The Rollers Roll evenly—never Skew or Slide



Greaves No. 2H Universal and Plain Horizontal Milling Machines use Orange Cage Type Needle Bearings in the Rapid Traverse, eliminating friction which caused overheating of former bearings. Greaves Machine Tool Div. of J. A. Fay & Egan Co. has used these bearings for 7 years with excellent results.

Many advantages for your equipment

The aligned-roller action of Orange Cage Type Needle Bearings gives you a true anti-friction, non-skewing needle bearing of high load capacity and small space requirements, with the following bonus values for your installations:

- **True-running in any position . . . horizontal—tilted—vertical—or overhung mountings.**
- **Less affected by misaligned mountings or uneven loading.**
- **Successful on relatively high speed applications.**

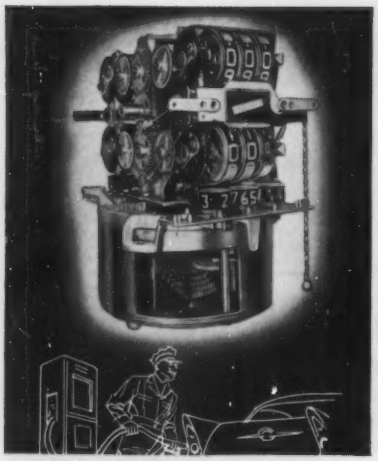
Orange Cage Type Needle Bearings are fully interchangeable with conventional needle bearings, in a complete range of stock sizes from ½" to 8" shaft diameter. Stocks and engineering service in all industrial areas.

•Write for Engineering Manual M-56, giving construction, capacities, dimensions, etc.

ORANGE ROLLER BEARINGS

ORANGE ROLLER BEARING CO., Inc.
556 Main Street, Orange, N. J.

Needle Bearings — Staggered Roller Bearings
Journal Roller Bearings — Thrust Roller Bearings
Cam Followers



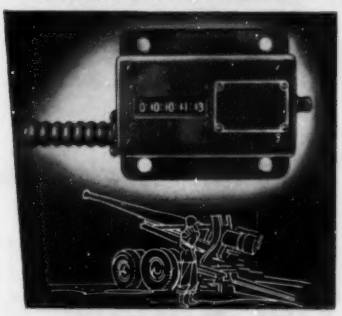
Computing Head for Gasoline Pumps

"Master Meter Duplicator" prints receipts for fuel oil delivered from trucks

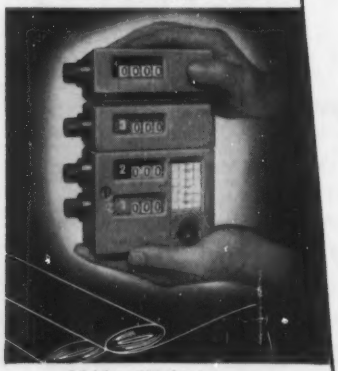
"Vary-Tally" Multi-Unit Reset Manual Counter

Everyone Can Count on VEEDER-ROOT

Rev-Counter for all types of engines



Recoil Counter for new 280 mm atomic cannon



2-3-4 Convertible Counters (and others) for textile machinery

Fuel-Remaining Counter for aircraft . . . subtracts as fuel is used

Everywhere you look in everyday life, you see a familiar face . . . the face of a Veeder-Root Counter or Computer. From gasoline pumps to fuel oil trucks to textile mills . . . in the home, on the farm, in business and commerce, in modern automated industry . . . Veeder-Root standard and special devices are keeping everything under *Count*rol . . . manually, mechanically, electrically. And the mathematical probabilities are mighty high that *you* can count on Veeder-Root, too . . . to your advantage and profit. Why not let us figure out how, *right now*?

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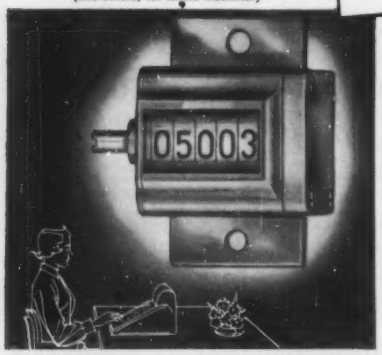
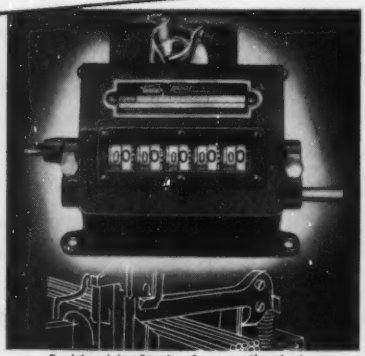
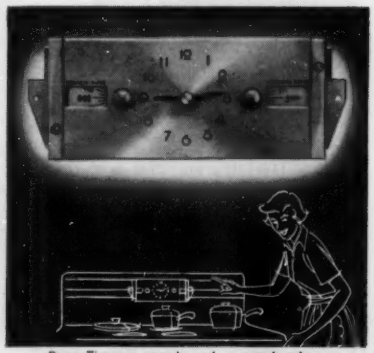


Small Square-Case Counters for office and other machines



Predetermining Counters for preventing short and over-runs on production machines



Range Timer . . . easy to read . . . easy to set

STOCKS OF STANDARD COUNTERS AVAILABLE AT — Greenville, S. C. • Chicago 6, Ill. • New York 19, N. Y. • Los Angeles • San Francisco
Montreal 2, Canada • Offices and Agents in Other Principal Cities

by vibration to provide accurate delays from 3 milliseconds to 30 sec. Timer is 2 x 2¼ x 3⅛-in.;

weight is 9 oz. Electrical rating is 105 to 125 v, 360 to 1200 cps; 60-cycle and dc units are also available. **G. C. Wilson & Co.**, Huntington, W. Va.

Circle 740 on page 19

Circuit-Component Kit

speeds construction of plug-in units

Chassis and terminal card assortment provides flexible series of basic components for mounting, packaging, housing or connecting circuitry. Circuitry may be subdivided by function into individual plug-in units that slide in, lock, or eject with half turn of handle on front panel. Plug-in chassis mount in mobile or portable racks for easy installation. Front-panel indicators and check points for in-out wiring on each plug-in unit allow fast chassis checks or replacement. Kit, with aid of unit planning sheets supplied, enables planning of all functional circuit units, component layouts, and housing sizes on drawing board in one step. **Alden Products.**, Brockton, Mass.

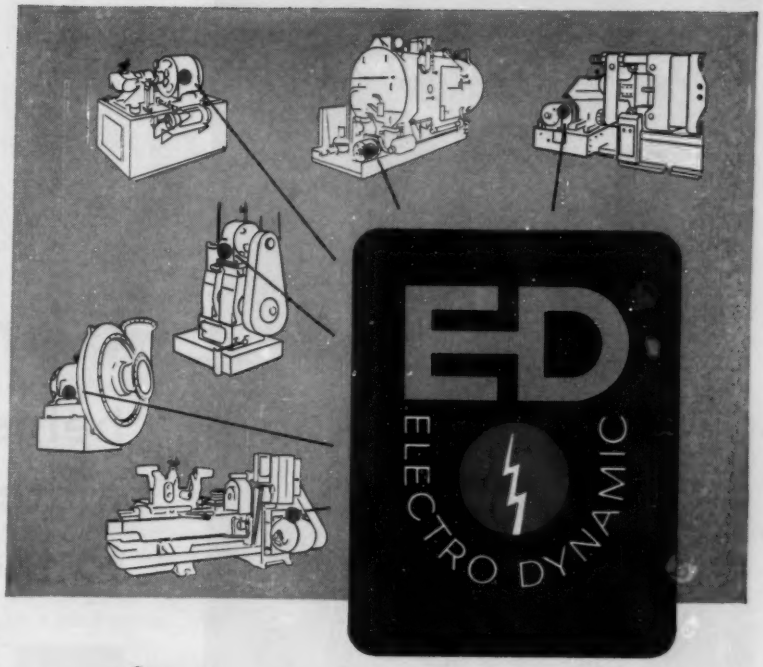
Circle 741 on page 19

Ceramic Gold Finish

for architectural use

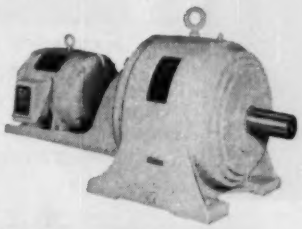
Ceramic gold 22-carat finish for architectural use makes possible the economical use of gold finishes in curtain wall construction. A thin application of 22-carat gold dust in solution is fused into the surface of the ceramic, giving a permanent bond. Since the ceramic application makes the finish more stable than the gold itself, only a thin application is needed. **Bettinger Corp.**, Waltham, Mass.

Circle 742 on page 19



STANDARD MOTORS

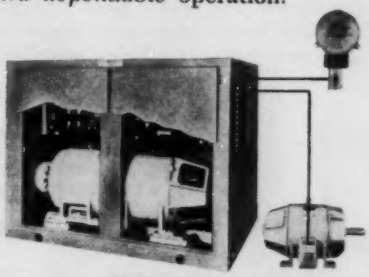
THIS EMBLEM IDENTIFIES EXTRA DEPENDABLE INDUSTRIAL MACHINERY



GEAR-ED-MOTORS

The red *power spot* on industrial machinery means "Powered by Electro Dynamic." Such machinery relies with confidence on the *extra dependability* of Electro Dynamic motors, the proven industrial motors which give industrial equipment *extra dependable* operation.

SELECTRON VARIABLE-SPEED DRIVES



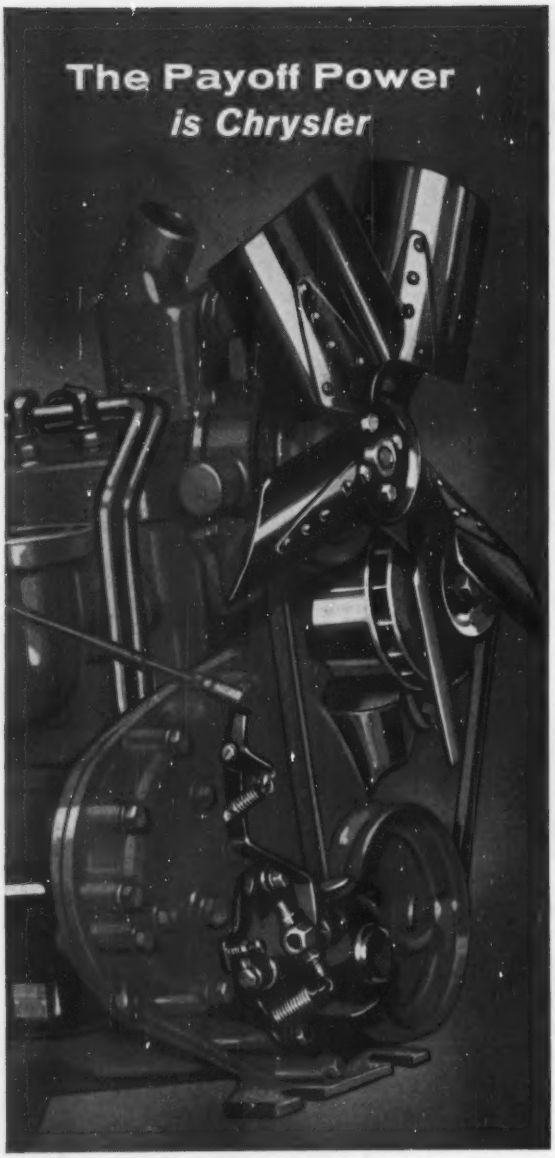
SELECTROL VARIABLE-SPEED DRIVES

ED ELECTRO DYNAMIC

DIVISION OF GENERAL DYNAMICS CORPORATION

BAYONNE, NEW JERSEY

GD GENERAL DYNAMICS



Chrysler

helps you match the power to the problem

You know best the power needs of your product. You know the special speed factors, load factors, operating demands, job conditions that make that product an individual engineering problem. It's your product. Your problem. We can't solve it *for* you. *But we can help.* Chrysler, you see, is not only the most mechanically efficient industrial power plant you can specify—it is also the most adaptable to varying requirements. *That's a fact.* For more facts check the specifications below. Write for complete technical information.

FOR YOUR FILES

Chrysler Industrial Engine Specification Booklet. Includes engine specification, performance data, power curves for all models. Write Dept. C-2, Industrial Engine Division, Chrysler Corporation, Detroit 31, Michigan.

SPECIFICATIONS—CHRYSLER INDUSTRIAL ENGINES

	Ind. 30	Ind. 31	Ind. 32	Ind. 33	Ind. 52	Ind. 56-A
No. of Cylinders	6	6	6	6	8	8
Type of Engine—4 Cycle	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
Bore—Inches	3 1/8	3 1/8	3 7/8	3 7/8	3 7/8	3.94
Stroke—Inches	4 5/8	4 5/8	4 1/4	4 1/4	3 1/4	3.63
Displacement—Cu. In.	230	230	265	265	270	354
Compression Ratio	7.0	7.0	6.8	6.8	7.5	7.6
Valves—Arrangement	L	L	L	L	OHV	OHV
Camshaft Drive	Silent Chain	Gear	Silent Chain	Gear	Silent Chain	Silent Chain
Engine Width*	23 1/16"	23 1/16"	23 3/8"	23 3/8"	30 3/8"	28 13/16"
Engine Length*	32 7/16"	31 13/32"	32 19/32"	33 11/16"	29 31/32"	31 1/32"
Engine Height*	34 1/2"	32 27/32"	32 29/32"	32 29/32"	34 1/4"	34 21/32"
Engine Weight*	575 lbs. (approx.)	610 lbs. (approx.)	740 lbs. (approx.)	760 lbs. (approx.)	712 lbs. (approx.)	845 lbs. (approx.)

*Dimensions vary with equipment.

Specifications subject to change without notice.

Chrysler

INDUSTRIAL ENGINES

INDUSTRIAL ENGINE DIVISION • CHRYSLER CORPORATION

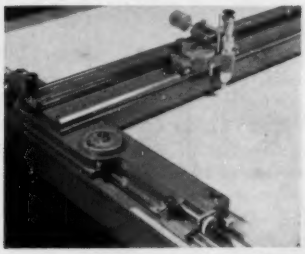
ENGINEERING DEPARTMENT

EQUIPMENT

Plotting Instrument

plots radii from 12 to 40 in.

Coordinatograph plots points along x and y co-ordinates within 0.001-in. and is used for aircraft lofting, gage charts, and laying out small parts. It is also used to plot blades in a stack or flow patterns for turbine blades, to establish co-



cordinate positions precisely for chart and map makers, and to plot reticules or targets for instrument manufacturers. Working area is a 47½ x 47½-in. table, made of vertically laminated wood strips. Radii from 12 to 40 in. can be plotted. Pricker-point unit has a seven-power microscope so that the point can be observed and plotted in a single set-up. **Aero Service Corp.**, 210 E. Courtland St., Philadelphia 20, Pa.

Circle 743 on page 19

Rocket Flight Simulator

tests acceleration characteristics of instruments

Automatic test system subjects acceleration-sensitive devices to entire range of acceleration and deceleration forces encountered during rocket and missile flight, duplicating any two-stage flight during each test. Unit consist of acceleration - deceleration, program, and data recording units. Acoustic specimen cavity and special microphone permit audio data sensing

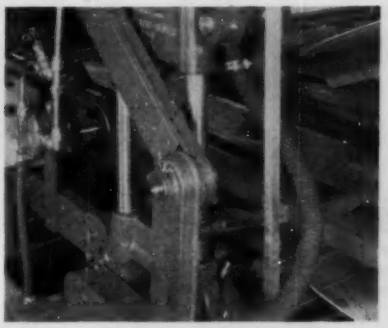
(*Continued on Page* 208)

Here's good news for designers

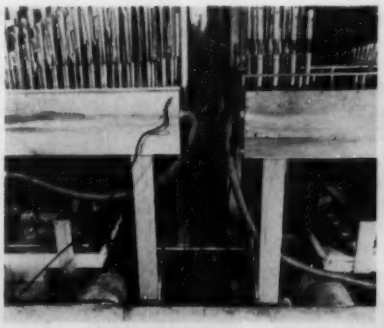
FLEXFLYTE *and* SPIRATUBE

FLEXIBLE DUCTING CAN SOLVE MANY A DESIGN PROBLEM

See how 3 manufacturers solved tough ducting problems with Spiratube® and Flexflyte®



Case #1 Industrial packaging manufacturer builds a gluing machine with a circulating glue system. Used Flexflyte LR-3 1⅛" diameter in 12-foot lengths. Takes up less space, has greater strength than conventional hose. Flexflyte is much easier to install and service and does not kink, even when bent on a small radius.



Case #2 A pipe organ manufacturer uses Flexflyte-U in diameters of 1" through 8" for air ducts. This tubing is easy to install and easy to maintain and is long lasting.

Case #3 A manufacturer offers a dryer using Spiratube which can be installed on any combine, enabling farmers to harvest grain regardless of humidity and surface moisture.

These cases from our recent files may suggest ways in which Flexflyte and Spiratube can solve *your* tough ducting problems. Write today — outlining your requirements — and we'll show you how these lightweight, completely flexible ductings can go to work for you! Available in diameters of less than 1" to 30" with special fabrics and coatings for wide temperature and pressure applications.

Flexible Tubing

CORPORATION

GUILFORD, CONNECTICUT • LOS ANGELES 64, CALIFORNIA

Flexible Tubing Corporation, Dept. 182, Guilford, Connecticut
Please send me more information on Flexflyte and Spiratube.

Name_____

Title and Company_____

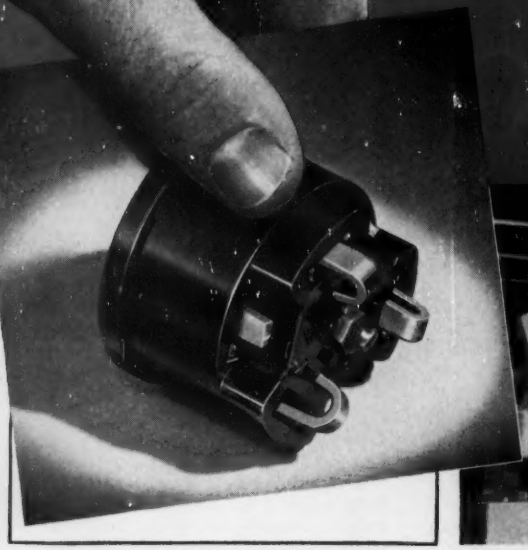
Address_____

City_____ Zone_____ State_____

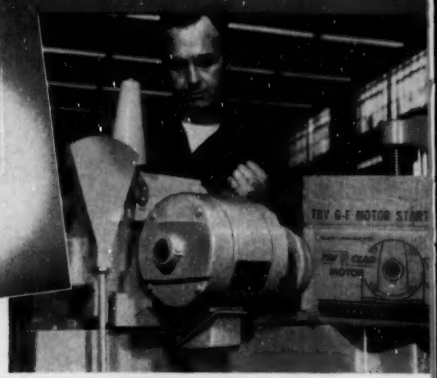
Circle 524 on page 19

NEW Inherent General

PERMA-NUMBERED LEADS, always easy to identify even after cutting or taping, can save you time on your motor installations.

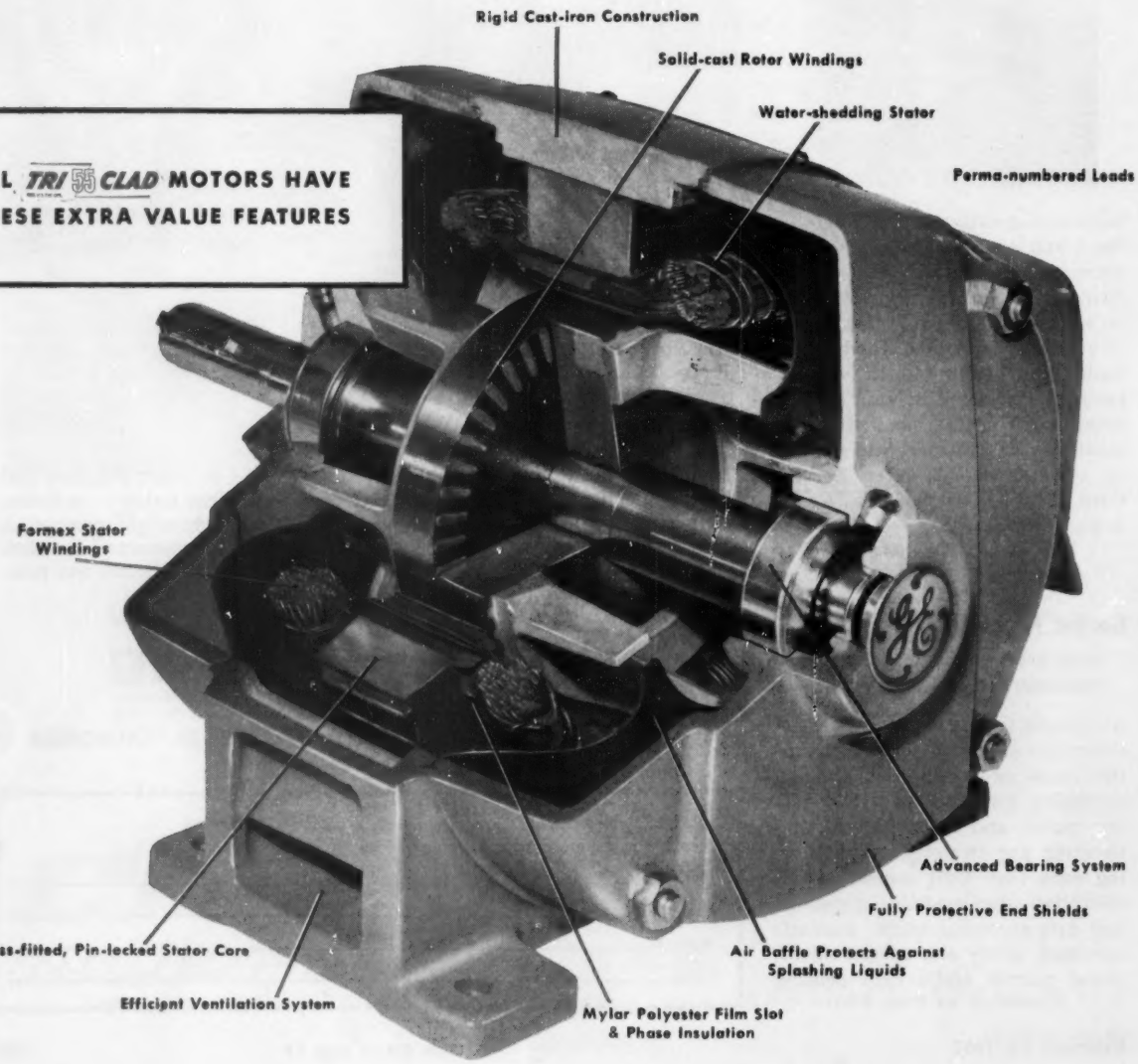


INHERENT PROTECTION is now available as an optional feature on Tri/Clad 55 *poly-phase* motors (1-5 hp)—another G-E "first."



CAST-IRON FRAME and end shields of these motors provide greater rigidity to prevent motor from being twisted out of line.

ALL TRI 55 CLAD MOTORS HAVE THESE EXTRA VALUE FEATURES



protection now available on Electric TRI 55 CLAD polyphase motors*

REG U.S. PAT. OFF.

MYLAR† POLYESTER FILM slot and phase insulation has over 8 times the dielectric strength of ordinary paper insulation.

FORMEX†† MAGNET WIRE insulation will not break under the most severe conditions —resists heat-aging and abrasive dusts.

SILICONE DRI-FILM†† COATING applied to stator assembly of the motor provides protection against failure due to moisture.

*Built-in inherent protection is *now* available, for the first time in the motor industry, on Tri/Clad 55 polyphase motors (1-5 hp, dripproof, foot-mounted, 1800 rpm).

This extra-value feature, formerly restricted to single-phase motors, may now be specified as optional equipment on the majority of General Electric's full line of Tri/Clad 55 motors. It is designed to respond to both current and temperature to protect the motor from excessive overload currents, stalls, high ambient temperatures, etc.

Inherent protection is only one more example of the long line of quality features built into the Tri/Clad 55 motor line. For example:

IMPROVED OPERATING CHARACTERISTICS—The full load speed of Tri/Clad 55 motors averages 25 rpm higher than a similarly rated old-design motor.

BETTER USE OF SPACE—G.E. was the first to give you the NEMA smaller, lighter design without sacrificing full-power performance.

NON-WICKING NEOPRENE LEADS prevent water from running up the leads into vital electrical connections.

EASY-ACCESS CONDUIT BOX can be rotated to permit connection from top, bottom, or sides.

And this is only a fractional list of the many value-plus features you get with every G-E Tri/Clad 55 motor.

For more information on how Tri/Clad 55 motors can help improve your product, write Section 840-5, General Electric Company, Schenectady, N. Y., and ask for bulletins GEA-6240 and GEA-5980, or contact your nearby General Electric Apparatus Sales Office.

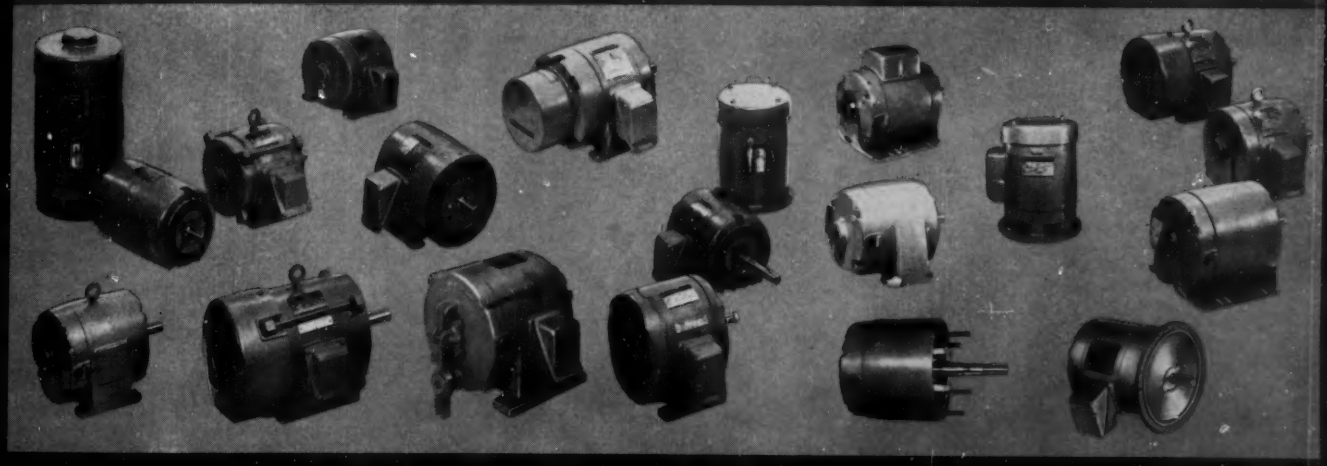
† *Reg. trade-mark of Dupont Co.* †† *Reg. trade-mark of General Electric Co.*

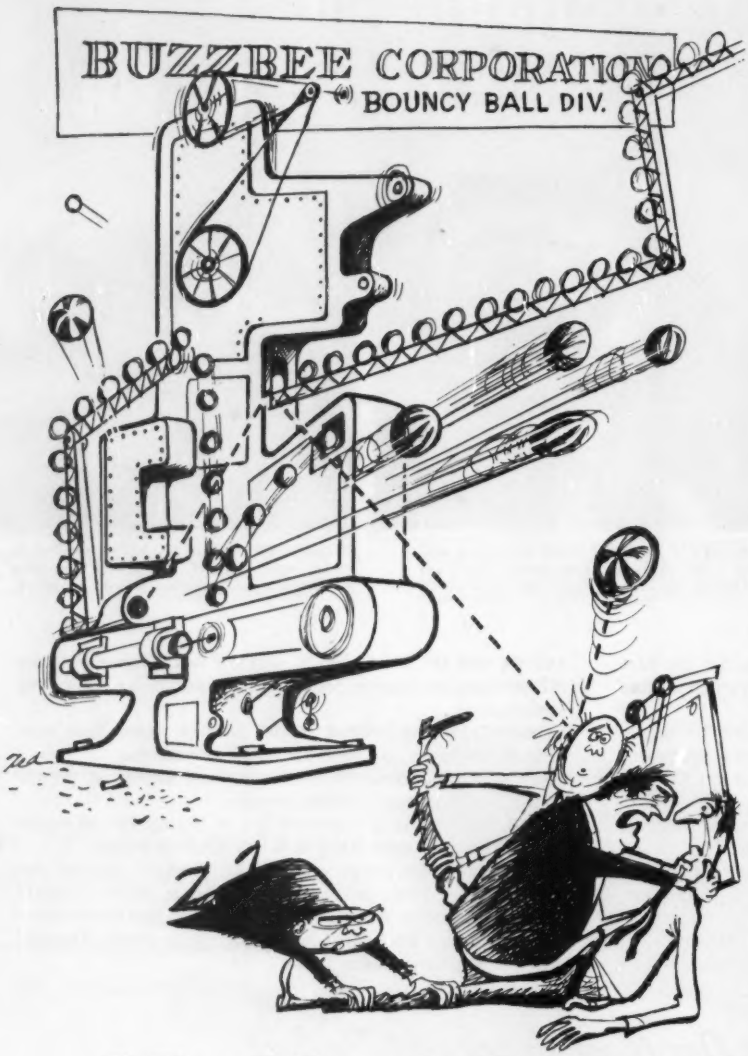
Progress Is Our Most Important Product

GENERAL ELECTRIC

G.E. OFFERS A FULL LINE OF TRI 55 CLAD MOTORS

REG U.S. PAT. OFF.

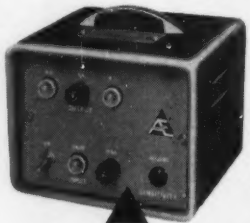




O.K... O.K..... So it's back to the old drawing board!... BUT THIS TIME REMEMBER AUTRON! **A·U·T·R·O·N!**

Mr. Buzzbee seems a bit put out at the output of his Bouncy Ball Div. His Chief Engineer seems to have been Nominated for Oblivion by Mr. B. His wrath is justified. For a long time, he has been screaming for a really reliable and small multi-purpose controller which would provide various options of control functions useable with a multitude of sensing elements for many farfetched applications. The upshot of this fateful scene is that the Buzzbee Chief Engineer shot up in Mr. B's. estimation by ordering a dozen of Autron's 6330 Heavy Duty Miniature Controllers. ($74 each, quan. 10-100.) If there's a Control Problem* in your life, you might need a 6330 too.

*Not applicable to control of Coffee Breaks or Water Fountain Trips.



Model 6330 is a heavy duty miniature controller that answers the need for a compact, flexible and rugged electronic switch capable of receiving any one of a wide variety of inputs at very low voltage and power levels and delivering up to 500 watts of power to a controlled circuit.

For further details on the 6330 Controller and other items in our line of reliable control products write today...

Attn: Mr. M. Day

Autron ENGINEERING, INC.

1254 WEST SIXTH STREET • LOS ANGELES 17, CALIF.

Circle 526 on page 19

Engineering Equipment

(*Continued from Page* 205)

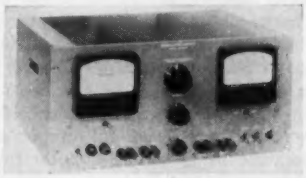
so that hermetically sealed units may be tested. Flywheels accelerate a device from 2 to 125 *g* in 200 mu sec; braking time is 100 mu sec minimum. Maximum flight time is 55 sec. Recording unit is a four-channel oscillograph recorder. Nontechnical personnel can operate simulator. **Magnavox Co.,** Dept. N. P., Fort Wayne 4, Ind.

Circle 744 on page 19

Power Supply

has recovery time of ½ millisecond

Low-voltage high-current power supply for transistor work and other uses requiring excellent regulation and microsecond response has output of 0 to 50 v dc (con-



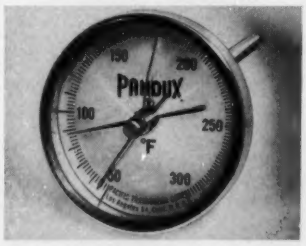
tinuously variable) without switching. Current is 0 to 1000 ma max. Full output current is available without derating throughout entire range. Recovery time from 0 to full load is 0.5 millisecond; full load to removal time is 0.25 millisecond. **Dressen-Barnes Corp.,** 250 N. Vinedo Ave., Pasadena, Calif.

Circle 745 on page 19

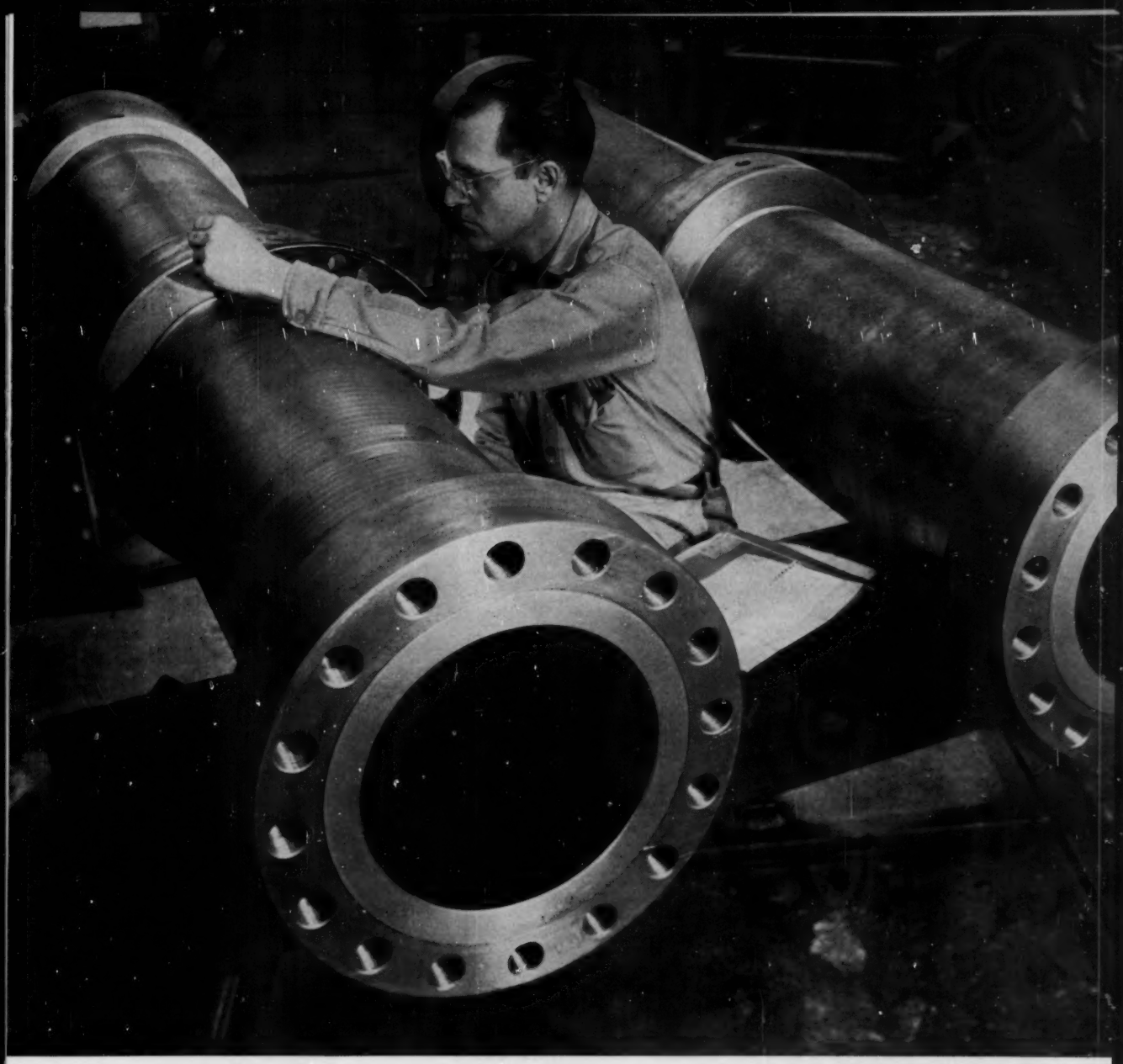
Stem Thermometer

indicates total temperature excursion

Stainless-steel stem thermometer with maximum and minimum in-



dicators provides measurement of total temperature excursion. Hands can be reset whenever required. Accuracy is 1 per cent full



OD 15 in., Right on the Nose

That was one of the specifications: outside diameter, 15 in. Very little tolerance; had to be almost exact. And it was, when it came from the Bethlehem machine shops for checking. Right on the nose!

There were other interesting specs that applied to this Bethlehem forging, and its twin. The two pieces are return cylinders for an extrusion press. The buyer required that they be 100¼ in. long. Bore was to be 1 ft for a distance of 87½ in.; then 7¾ in. for the remainder of the length. Ticklish work? Sure! But Bethlehem machinists were equal to it.

Bethlehem is recognized as a producer of forgings in all sizes—from the heaviest ever needed to pygmies weighing a pound or less. But we'd like to emphasize that Bethlehem services go beyond this point. The order described here is a good example. Whatever we forge, we can machine—and do a thoroughly expert job.

With its integrated set-up, Bethlehem is always able to handle your requirements. Call us when in the market for large or small forgings, and give us machining specifications. They'll be followed to the letter.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

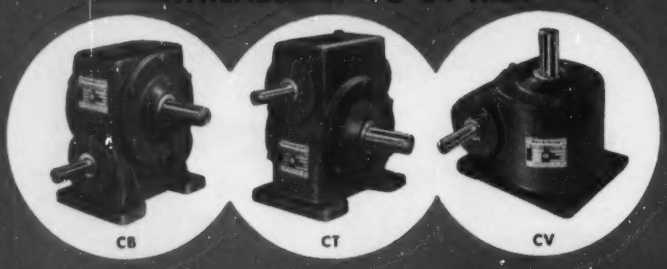
BETHLEHEM STEEL

BETHLEHEM STEEL

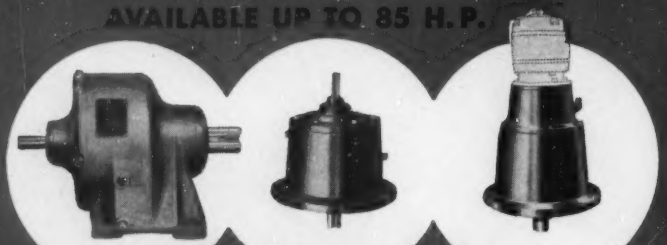
Circle 527 on page 19

VERSATILE PERFORMANCE for your BIG JOBS, too, in SPEED REDUCTION

WINSMITH WORM GEAR REDUCERS
AVAILABLE UP TO 34 H.P.



WINSMITH DIFFERENTIAL REDUCERS
AVAILABLE UP TO 85 H.P.



The stock line of Winsmith Speed Reducers offers a wide variety of rugged, heavy duty units designed to handle *all your* speed reduction problems involving high input horsepower. Worm gear reducers are available in horizontal or vertical types, with right angle or parallel shafts... worm on top or worm on bottom. The Winsmith Differential line offers equal versatility with three stock types — Horizontal, Flange Mounted, or Vertical Motorized.

It will pay you to standardize on Winsmith — the most complete line for all your speed reduction jobs — big or small — from 85 h.p. down to 1/100 h.p.

WINSMITH SPEED REDUCERS

COMPLETE ENGINEERING DATA on hundreds of types and sizes of Winsmith reducers is included in Catalog #155 — write for your copy today.

WINSMITH, INC. 16 Elton St., Springville, (Erie County), N. Y.

Engineering Equipment

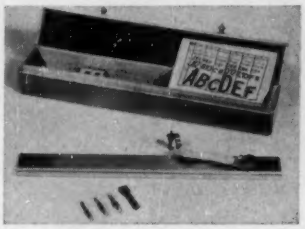
scale range; seven ranges are available. **Pacific Transducer Corp.**, 11836 W. Pico Blvd., Los Angeles 64, Calif.

Circle 746 on page 19

Lettering Set

speeds ink or pencil lettering

Device has 15-in. nonslipping guide holder, adjustable scriber, and template scriber guide, with capital



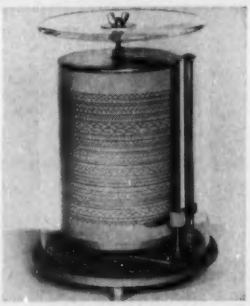
and lower-case letters and numerals for five heights: $\frac{1}{8}$, $\frac{3}{32}$, $\frac{3}{16}$, $\frac{1}{4}$ and $\frac{5}{32}$-in. Instrument adjusts to more than 100 positions. **Alvin & Co.**, Windsor, Conn.

Circle 747 on page 19

Chart Recorder

uses wax-coated waterproof chart

Compact operations or events recorder has drum that rotates at speeds from 4 min to 24 hr per turn and graphically records when a machine or device is operating. Stylus produces slight spiral trac-



ing on chart paper that has adherent layer of white opaque wax crystals. Pressure of stylus exposes contrasting color of paper beneath wax. Waterproof chart is 6 by 14 in. and holds 400 lineal in. of recording. **Gorrell & Gorrell**, Haworth, N. J.

Circle 748 on page 19

Professional Viewpoints . . .

Interference-Fit Thread

for studs, bolts and screws

To the Editor:

The article "Interference-Fit Thread" (MACHINE DESIGN, September 6, 1956) by William G. Waltermire was very interesting and enlightening. Mr. Waltermire and his associates deserve much credit for their persistence and thoroughness in carrying out the preliminary planned program and then in the field application of the conclusions from the program.

To say the least, the claims of easy assembly with such high maximum interferences, as are indicated by Mr. Waltermire's tables, are startling. But the quality of the personnel and apparatus involved and the thoroughness and care with which the preliminary tests were made and reported all make the report irrefutable. Later field application has been too limited to allow final conclusions to be drawn but it is hoped that wider application of the tables will accumulate experience for corroboration or further study. My comments are offered to help toward this end.

The principle of reducing the major diameter of Class 5 stud threads has been applied for at least twelve years for the more expensive studs where particularly difficult problems were present. High success in driving such studs has been achieved but often the major diameter reduction has been only one of several concurrent features so that there has been very little conclusive proof as to which feature contributed most to success. We believe that in only a few cases has success been absolute. There are too many variables in stud driving to expect to avoid occasional sticking, or occasional backing-out of studs, even when physical measurements appear to be within close specified limits.

In the published article are some typographical errors which should be presented to prospective users of the standard among MACHINE DESIGN readers. The needed corrections are:

1. Page 85, Table 1, second column, 1¼-7 size; change 1.234 (max) to 1.232 (max).
2. Page 85, Table 2, second and third columns, 1⅛-7 size; change limits from 1.0152 (min) and 1.0322 (max) to 0.9998 (min) and 1.0152 (max).
3. Page 85, Table 2, ninth column (Virtual Diam), 1⅛-7 size; change 1.0382 (max) to 1.0381 (max).
4. Page 85, top righthand column of text under heading, **Stud, Table 1;** in first line of Par. (a) insert words "of tolerance" between the words "equal in amount" and "to Class 3."
5. Pages 85 and 86, footnotes for Tables 1 and 3; definitions should be included for: D = nominal diameter, L = stud length, L_e = length of engagement, N = length of thread on nut end of stud.
6. Page 85, footnote for Table 1; T should be T_e.
7. Page 86, footnote for Table 3; T_e = length of interference threads on stud; T_h = minimum depth of thread (full) in hole.

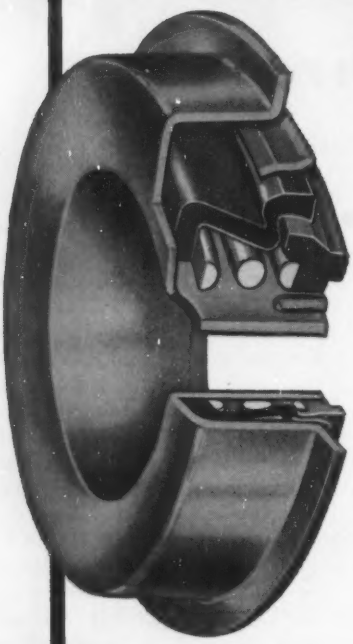
Mr. Waltermire has apparently used average stud OD and average hole ID to produce the mentioned 50 per cent thread engagement (top line of righthand column, page 85), but in the rare chance of minimum material conditions of both stud and hole, this could produce just over 42 per cent calculated engagement, with some added engagement due to spin-up in threading and flow of interference metal during driving. It is doubtful that this possible extreme condition would create any undue tendency to stripping of the threads. It might be more significant if applied to fine threads.

Doubtless, if Mr. Waltermire had been able to expand his article, he would have included some warnings. Anyone who has driven studs realizes that a table of dimensions is not a complete cure-all for the difficulties likely to be encountered with so many combinations of variables as occur in stud fits. We believe that no design figures will give even reasonable satisfaction in driving stud fits unless extreme care is taken to remove chips and dirt from the threads of both stud and hole before engaging them. Even small particles in contact areas can cause already extreme contact pressures to increase to a point where welding begins and is followed by progressive pick-up of metal. Even inclusions of a gritty nature in the steel of which the studs are made can cause the same trouble as extraneous dirt, so the use of "clean" steel is extra insurance against trouble. Bruises on the threads produced by poor packing for shipment and later handling also represent potent sources of trouble.

The lubricant, ground rubber dispersed in water, which was used to drive the studs in the preliminary program was relatively unusual and strikingly different from the mixture of white lead in oil commonly used. Incidentally, the addition to the latter mixture of up to 25 per cent of colloidal and powdered graphite does minimize the risk of seizure of the studs while being driven, but it also makes fits, which without the graphite addition would border on being too loose, still looser.

It is to be hoped that users of the dimensions published by Mr. Waltermire will report to him the results of their practical experience with the new stud fits with, if possible, actual measurements of the studs and holes, quantities involved and driving condi-

YOU ASSURE...



✓ Greater Economy
✓ Better Performance

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SELF-ALIGNING

TYPE 11-A

Rotary Shaft

SEALS

BECAUSE:

1. **You save on production time.** The Type 11-A Seal is a low cost, compact, factory assembled unit. Its "pressed-in" cartridge-type construction makes for quick installation as equipment rolls by.

2. **One seal size fits several shaft diameters.** Retainer is so constructed that it does not contact the shaft, eliminating the need to "switch" seals when shaft specifications vary slightly.

3. **Damaging stresses are eliminated.** Since the entire unit remains stationary, the seal readily lends itself to applications involving high speed and vibration.

4. **Safeguarded against corrosion.** Metal spring utilized to maintain constant contact of sealing faces is fully enclosed in synthetic rubber bellows. This eliminates the need for costly corrosion-resistant spring materials.

"John Crane" Type 11-A Seals are recommended for temperatures to 212°F., pressures to 20 psi. Available in four stock sizes from ⅛" to ¼".

Contact "John Crane" engineers on your requirements today. Request illustrated catalog on complete line of seals for all services.

Crane Packing Co., 6425 Oakton St., Morton Grove, Ill. (Chicago Suburb). *In Canada: Crane Packing Co., Ltd. Hamilton, Ont.*

JOHN CRANE CRANE PACKING COMPANY 38 YEARS INDUSTRIAL PROGRESS

Professional Viewpoints

tions, including torques and speeds of driving.

—W. S. BROWN

A licensed professional engineer in New York and a recognized authority in fastener standardization activities, Mr. Brown has an interest in stud fits that dates from 1932. Since then he has been periodically involved in helping to solve difficulties in stud driving. In 1946, he became a member-at-large of ASA Sectional Committee B1 (Screw Thread Practice) and has been a member of several B1 subcommittees, some of which are still active. He is also a member-at-large of ASA Sectional Committee B4 (Limits and Fits) and of its active subcommittee. His comments are offered here in a private capacity.—ED.

To the Editor:

Mr. Brown's comments on "Interference-Fit Thread" are a big contribution to an understanding and knowledge of this subject. He has a critical editorial eye for catching errors and I agree with his corrections 1 to 4 inclusive.

His suggested corrections 5, 6 and 7 are also well taken. However, so far as the article is concerned, these definitions are included in the discussion as, for example, the text portions above Table 1, Page 85. So far as a standard to be developed from the article is concerned, his observations are entirely correct, and this has already been incorporated in the new standard now out for ballot, due largely to Mr. Brown's influence.

He correctly assumed that I had used average stud OD and average hole ID to produce the minimum 50 per cent thread engagement which I mentioned at the top of Page 85 of the article. In the actual calculations, the average percentage of thread depth ranged from 50 to 66 per cent. The chances, of course, of having a minimum stud OD and a maximum hole ID are very small. They are no greater than that of having a maximum stud OD and minimum hole ID combination. No danger is anticipated at all even when depth of engagement is on the fringe because, for one thing, the stud OD "spins-up" or the hole "spins-in" during assembly, thus increasing the thread depth as Mr. Brown points out. For another, the $1\frac{1}{4}$ D length of thread engagement is considerably greater than the approximate $2/3D$ length of engagement specified in *Screw-Thread Standards for Federal Services* (1950 Supplement).

On Page 95 of the foregoing government standard Figure XVI.2 shows curves for minimum length

Circle 529 on page 19

how Vacuum Metals FERROVAC solved critical surface problem for Bausch & Lomb . . .

The jewelers' rolls Bausch & Lomb use to roll gold-alloy wire for eyeglass frames must be *mirror-smooth*. Rolls of conventional air-melted alloys just didn't work out economically. A normal amount of nonmetallic inclusions in the metal meant they had to be ground and reground, polished and repolished, before the surface was satisfactory. And even then, many rolls had to be scrapped when finishing uncovered inclusion pits.

The solution to this problem proved to be Vacuum Metals FERROVAC® Airdi 150. A better finish was obtained without any regrinding—and the number of scrapped rolls fell to zero. Here's why: Vacuum-melting removes the gases which create nonmetallic inclusions in the molten metal before they get into the product. This means cleaner metal, smoother surfaces. What's more, vacuum-melting improves fatigue, creep and impact strengths . . . reduces brittleness.

Vacuum-melted metals are the answer to jobs where surface is critical—like gauge blocks, plug and ring gauges, rolls for aluminum foil—as well as many other specially demanding applications. They're available in most grades and sizes, including special ferrous and non-ferrous alloys. Write now for a free analysis sheet on which to describe your application. It will help us both decide how vacuum-melted metals can serve you best. ***Vacuum Metals Corporation, Division of Crucible Steel Company of America, P. O. Box 977, Syracuse 1, New York.***

VMC®

VACUUM METALS CORPORATION

Division of Crucible Steel Company of America

Circle 530 on page 19

SPECIFY OHIO GEARS

Rigid inspection control combined with the most modern gear cutting equipment produce top-quality gears at OHIO. The importance of using good gears cannot be over-emphasized. Real satisfaction is assured with Ohio Gear products.

Get in touch with our nearest distributor or contact the factory direct for efficient service.

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OHIO GEARS

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Professional Viewpoints

of thread engagement. The ratio of length of engagement to diameter runs from 0.53 to a little over 0.66. This bears out the previous statement. The ratio of $L_e/D = 1\frac{1}{4}$ for studs is almost double this. As the length of thread engagement is increased, depth of thread engagement becomes less critical.

In the article, Table 4 (Page 87) on design notes is intended to convey the warnings Mr. Brown emphasizes. He may be quite correct in regard to sensitivity to burrs, chips and dirt of assemblies made to the standard. However, by eliminating the real trouble-making culprits of the past, we feel the new standard is far less sensitive to normal variations of this type and of thread lead and angle.

I want to thank Mr. Brown for his interest in this subject and for his initiative in studying, searching and pointing out the errors in the article and in making some very excellent suggestions for improving it. This action is only natural because he has been a very active leader from the beginning in investigating this subject in discussions and research which led to its solution. His letter will, we hope, stimulate trial of the new standard by individuals and companies, followed by reports of results, both good and bad.

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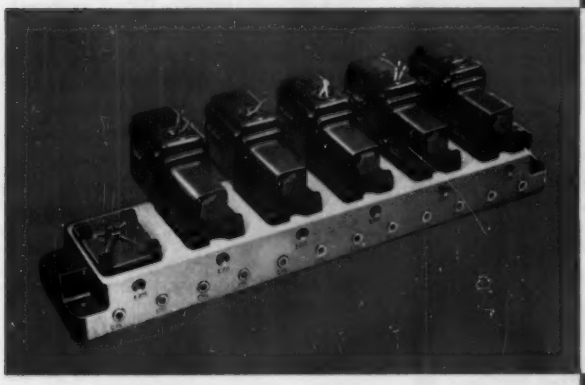

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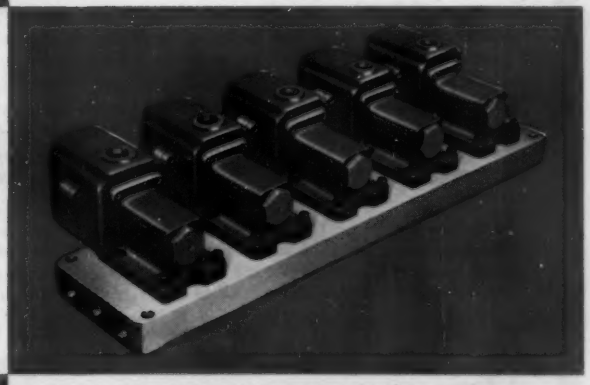

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Circle 532 on page 19

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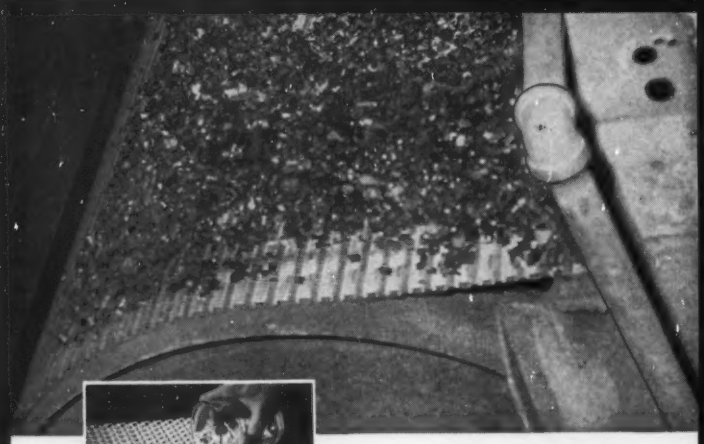

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Recent Books

Engineering in History. *By Richard Kirby, Sidney Withington, Arthur Darling and Frederick Kilgour;* 430 *pages,* 6 *by* 9 *in., clothbound; published by McGraw-Hill Book Co. Inc.,* 330 *W.* 42*nd St., New York* 36, *N. Y.; available from* MACHINE DESIGN, $8.50 *postpaid.*

This history of engineering from 6000 B.C. to the present was written by a combination of authors including both engineers and historians. The book provides a historical discussion of the interaction of engineering with society, presenting the history of engineering as one of many human activities and showing how various factors in the physical and cultural environment conditioned engineering advance and how, in turn, engineering has had its impact on the rest of society. Emphasis is placed upon the history of civil, electrical, and some aspects of metallurgical (iron and steel) and mechanical (power and transportation) engineering. Special branches such as military, naval and chemical engineering are not included.

The Diecasting Process. *By H. K. Barton;* 224 *pages,* 6 *by* 9 *in., clothbound; published by The MacMillan Co.,* 60 *Fifth Ave., New York* 11, *N. Y.; available from* MACHINE DESIGN, $5.00 *postpaid.*

Comprehensive, detailed, and up-to-date information is presented by this book for use in designing, making, buying or using diecastings. The book clearly shows exactly what features can and cannot be incorporated in a die-cast component and deals with specifications and quality standards. It also covers the machining of diecastings, quality of electrodeposited and organic finishes and the fabrication of assemblies containing die-cast components. Both the scope and the limitations of the

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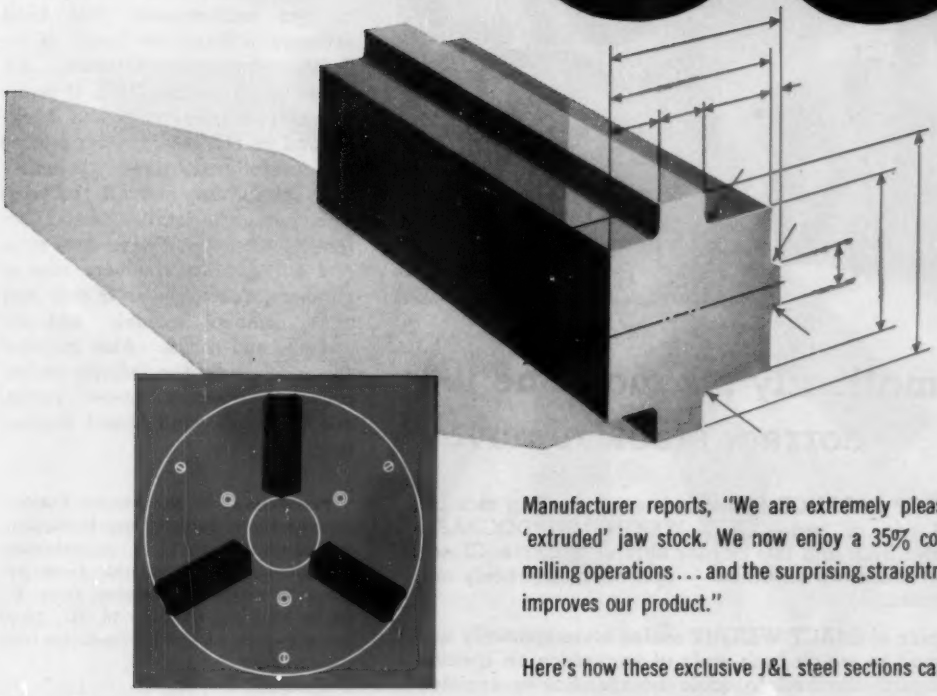

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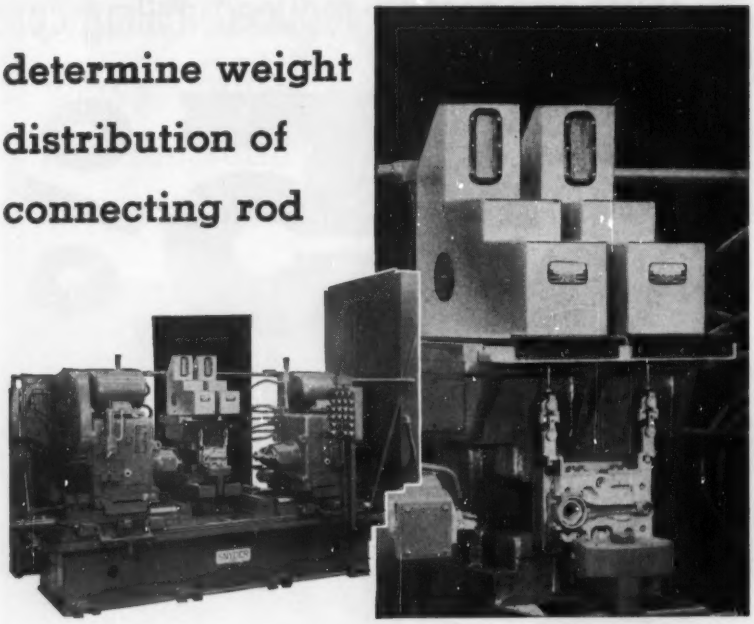
Circle 534 on page 19

Exact Weight Scales

determine weight distribution of connecting rod



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Circle 535 on page 19

Library

process are discussed impartially and much attention is paid to costs, including costs as compared with those in other precision manufacturing processes.

Infinite Sequences and Series. *By Konrad Knopp, translated by F. Bagemihl;* 196 *pages,* 5½ *by* 8 *in., published by Dover Publications Inc.,* 920 *Broadway, New York* 10, *N. Y.;* $1.75 *per copy,* $3.50 *clothbound.*

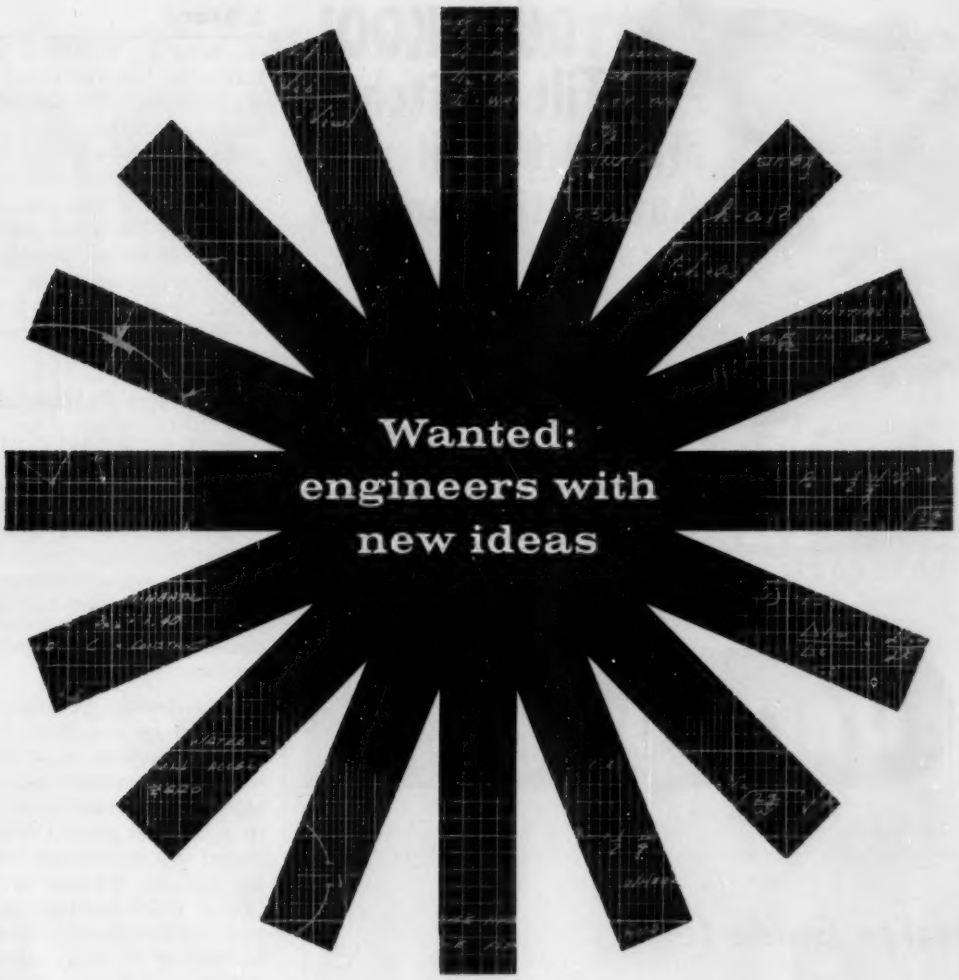
Concentrated upon two topics of modern mathematics, this book presents in detail the theory of infinite sequences and series. An introductory presentation, it is designed primarily to give a background or refresher. Foundations are carefully explained; all definitions are given, and all theorems proved in clear detail. Partial contents include sequences and sets, real and complex numbers, sets of numbers, functions of a real and of a complex variable, and sequences and series. Also included are main tests for infinite series, convergent series, power series, and numerical and closed evaluations of series.

Proceedings of the Second Conference on Radio Interference Reduction. 368 *pages,* 8½ *by* 11 *in., paperbound; published by and available from Armour Research Foundation, Dept. E.,* 10 *W.* 35*th St., Chicago* 16, *Ill.;* $6.00 *per set of two volumes (includes* 1954 *Conference).*

These two books comprise papers presented at the 1954 and 1956 Conferences, covering both theoretical aspects and contemporary developments in the field of electronic and electrical interference reduction. Papers discuss measurements, design techniques, practical suppression measures, and component developments.

A Scientific Sampler. *By Raymond Stevens, Howard Hamacher, and Alan Smith, editors,* The Industrial Bulletin, *Arthur D. Little, Inc.;* 413 *pages,* 6 *by* 9 *in., clothbound; published by D. Van Nostrand Co. Inc.,* 120 *Alexander St., Princeton, N. J.; available from* MACHINE DESIGN, $6.00 *postpaid.*

This interesting book is a collection of short essays from *The Industrial Bulletin,* of Arthur D.



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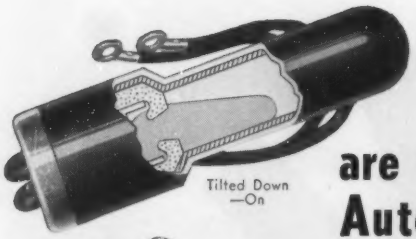
Circle 536 on page 19



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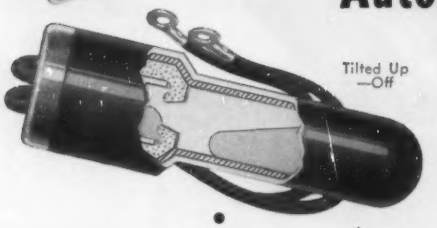

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Circle 537 on page 19

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Government Publications

Roller Bearing and Friction Bearing Technology for the Designer, PB 121366. *By K. Kollman and H. Hahn, Karlsruhe, Germany; 26 pages, 8 by 10½ in., paperbound; translated by Science Translation Service, University of Alabama for Bureau of Ships, USN; available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.; 75c per copy.*

This booklet contains papers delivered by the Study Group of Design Engineers in Stuttgart, intended to acquaint industrial designers with results of research in roller and plain bearings. Included are reports on roller-bearing systems, friction and lubrication of roller bearings, mixed friction and its effect on the boundary loading of friction bearings, calculation of the temperature of friction bearings, and highly loaded friction bearings.

Aluminum Coatings on Stainless Steel, PB 121487. *By J. E. Srawley, Naval Research Laboratories; 41 pages, 8 by 10½ in., paperbound; prepared by Naval Research Laboratories; available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.; $1.25 per copy.*

Coatings of hot-dipped aluminum on type 310 stainless steel did not impart substantially better resistance to fuel-ash constituents than the uncoated steel, according to this research. Tests of the aluminum coatings were part of a search for materials which will withstand corrosive attack of residual fuel-oil ashes on boilers and gas turbines. Although superior resistance has been predicted for the coatings, testing indicated that no useful protection was gained.

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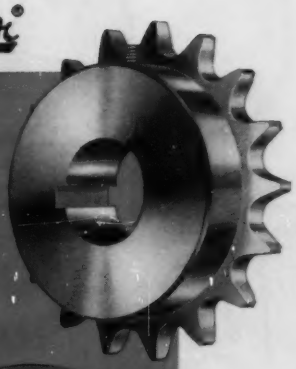

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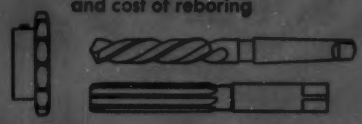

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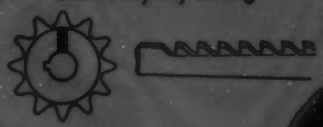

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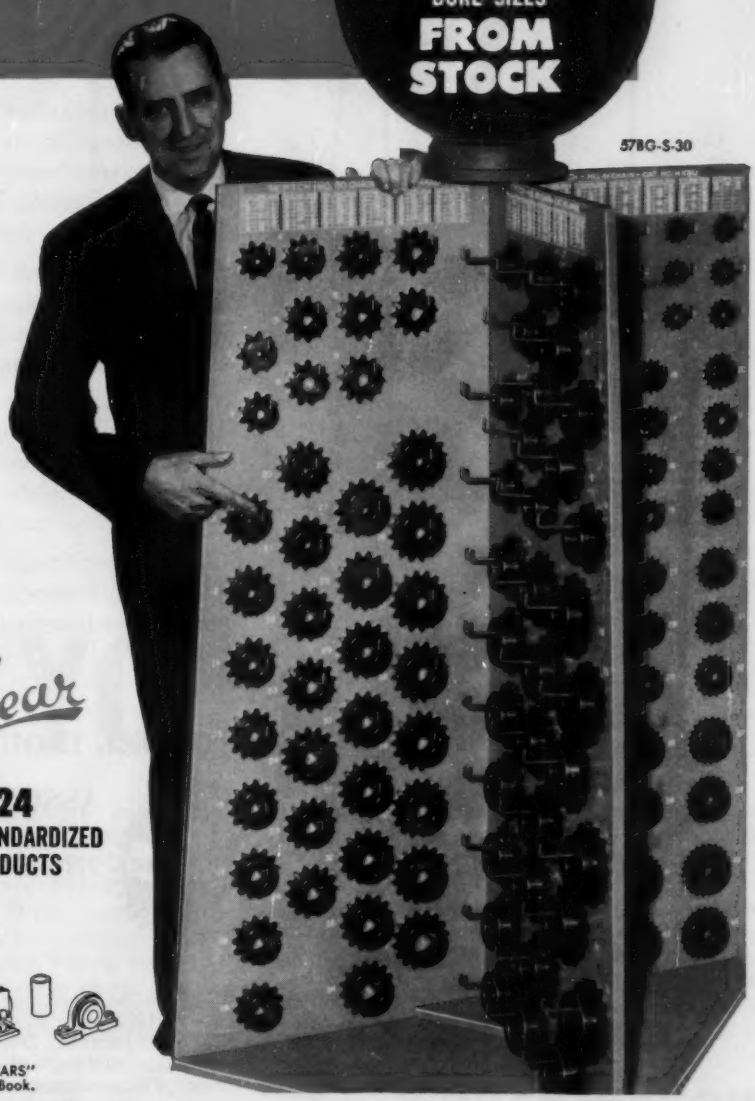

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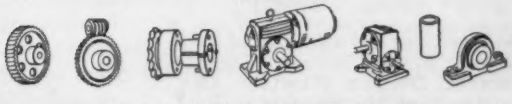

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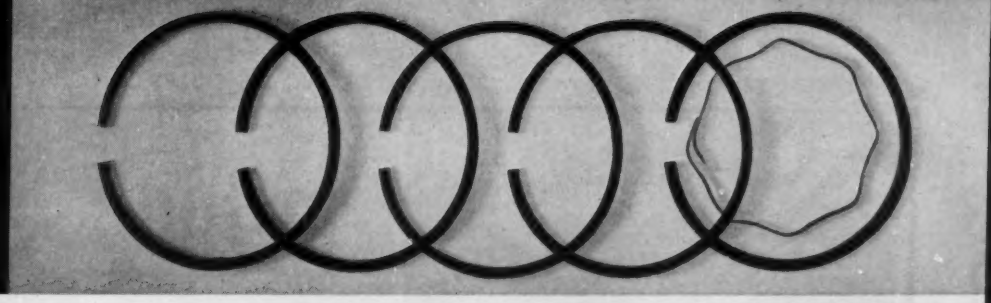
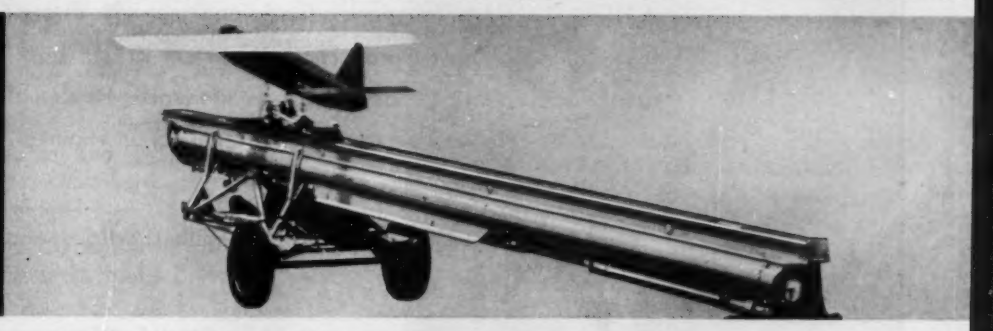


2. What should a compressor have in common with this freight train?

3. It operates with no impact. Can you name the part?

4. What "fires" this Navy target drone?



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Circle 539 on page 19

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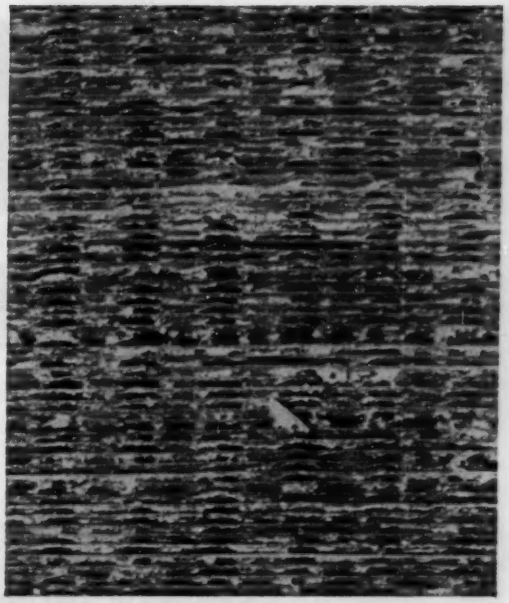
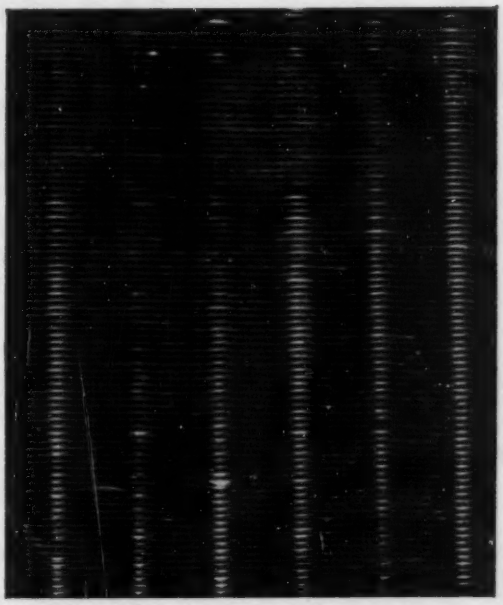


UNTREATED—Unretouched photo of section of aluminum heat exchanger after 1150 hours in salt spray. Note corrosion.



BONDERITE-TREATED—Unretouched photo of section of identical aluminum heat exchanger after 1150 hours in salt spray. Note absence of corrosion.

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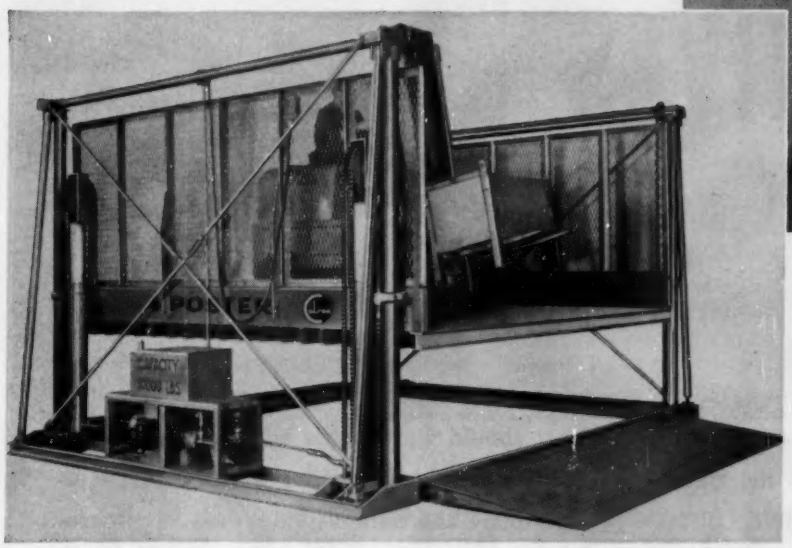

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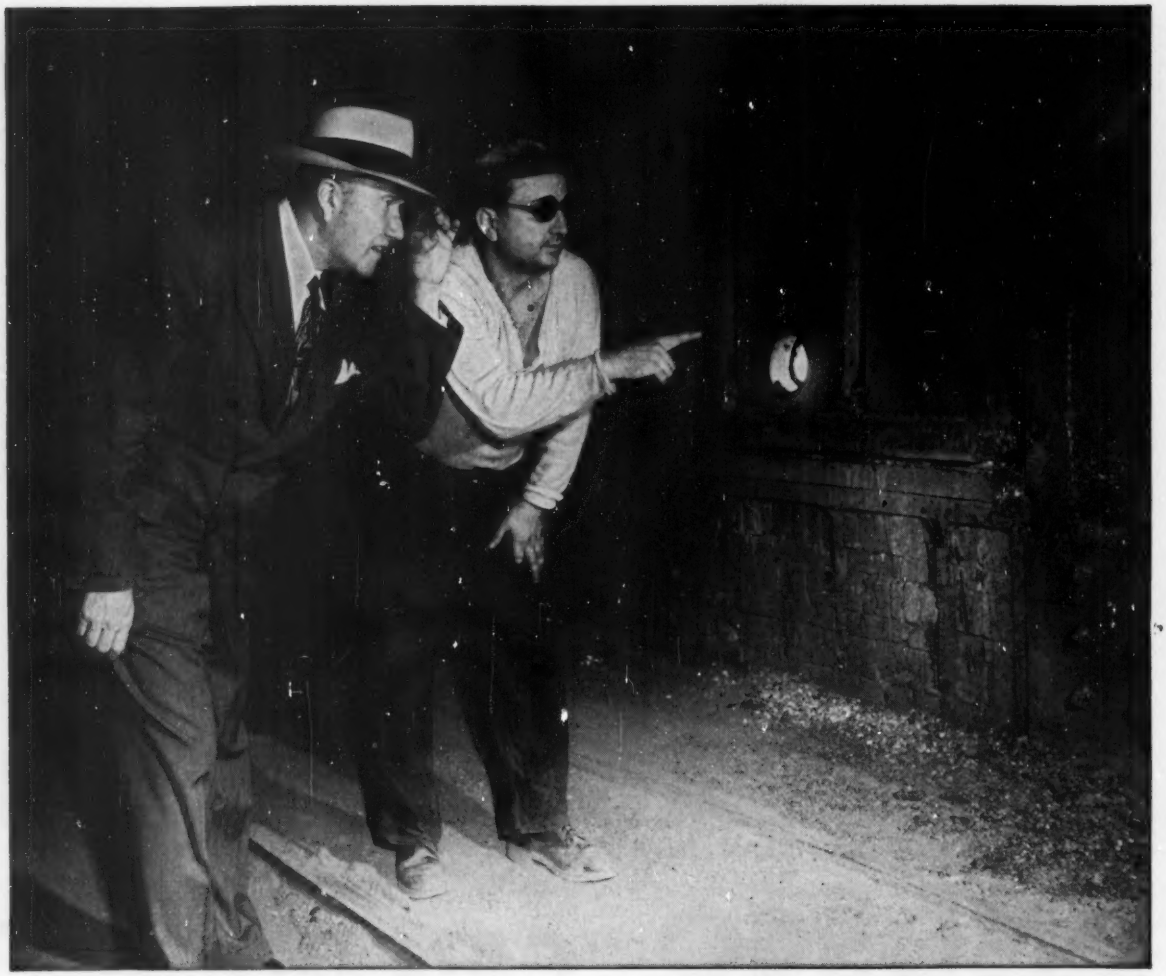

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Miniature Instrument Ball Bearings

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Subject: **MEASUREMENT OF RADIAL RUNOUT**

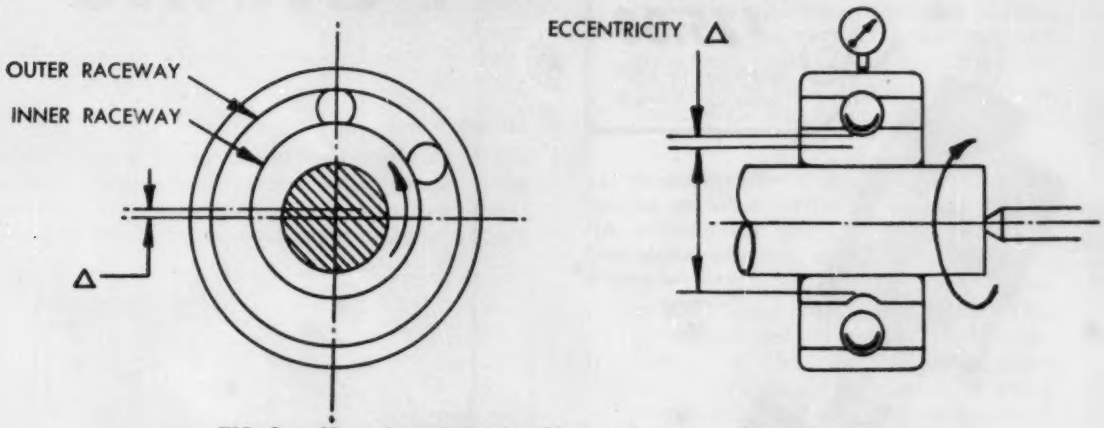

FIG. 1 — *Measuring eccentricity of bore with respect to inner raceway.*

Occasionally questions are raised about the methods of measuring "radial runout" and "out-of-round". In order to define "radial runout" properly, a discussion of "eccentricity" and "out-of-round" is necessary.

The amount of out-of-round, or lack of roundness of a given part (inner or outer ring or ball) is the difference between the maximum and the minimum diameter of the part in question.

Eccentricity refers to the distance between the centers of two circles. Concentricity refers to the exact coincidence of the centers of two or more circles. In high grade instrument bearings there is a very small tolerance on the permissible eccentricity between the bore and the inner ring raceway, and likewise between the outside diameter and the outer ring raceway.

Inner raceway out-of-round is measured by forcing the ring between the rounded edges of two discs, one of which is fixed and the other of which is mounted on the indicating mechanism. The difference between the maximum and minimum readings reveals the amount of out-of-round. Out-of-round of the outer ring raceway is measured by placing the ring over two rounded points which engage the raceway. One point is fixed and the other actuates an indicating mechanism. As the ring is rotated, the difference between the maximum and minimum readings indicates the degree of out-of-round.

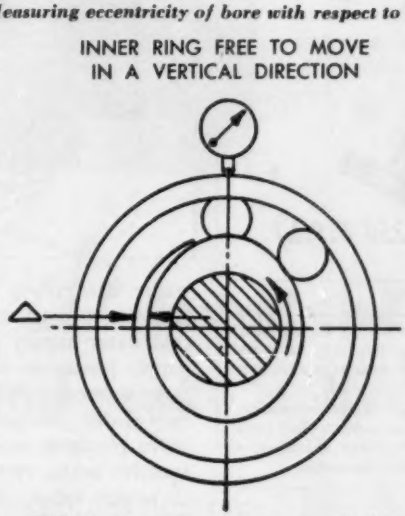

FIG. 2 — *Inner raceway is out-of-round, although concentric with bore.*

The true amount of eccentricity between the bore and the inner ring raceway can be measured, providing these circles are not out-of-round, by mounting the assembled bearing on a slightly tapered arbor, applying a calibrated indicator on the center of the stationary outer ring, and then slowly rotating the arbor. The eccentricity is the difference between the minimum and maximum gage reading as the arbor is rotated through one revolution. Similarly, the eccentricity of the outer ring is measured by the difference in the dial readings with the arbor and inner ring held stationary while the outer ring is rotated one revolution. *Fig. 1* shows the set-up with an inner raceway which is eccentric with respect to the bore.

In the case above it has been stipulated that the bore and inner raceway must not be out-of-round, for only under these conditions is the true eccentricity measured.

If the raceway is out-of-round, while being either eccentric or concentric with respect to the bore, the out-of-round will be transmitted to the indicator, thereby influencing the reading. A condition in which the inner raceway is out-of-round although concentric is shown in *Fig. 2*.

In view of the fact that the majority of bearing rings will unavoidably be somewhat out-of-round and eccentric, however slightly, it is obvious that the measurement described above indicates neither true eccentricity nor true out-of-round but a summation of the two quantities. Hence the measurement is more correctly termed *radial runout*.

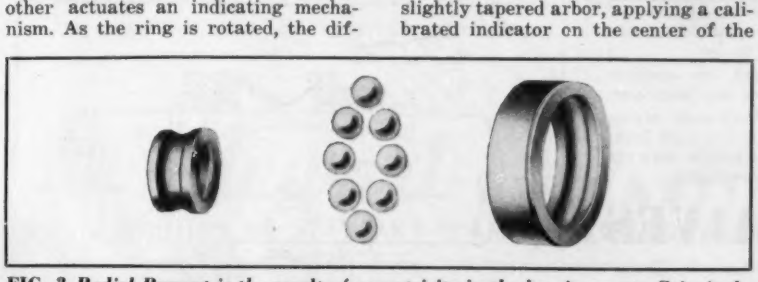

FIG. 3 *Radial Runout is the result of eccentricity in the bearing parts. Principal factors producing it are eccentricity between bore and raceway of inner ring (left) and between raceway and outer diameter of outer ring (right). Out-of-round balls offer negligible effect, since effect tends to cancel out as balls roll.*

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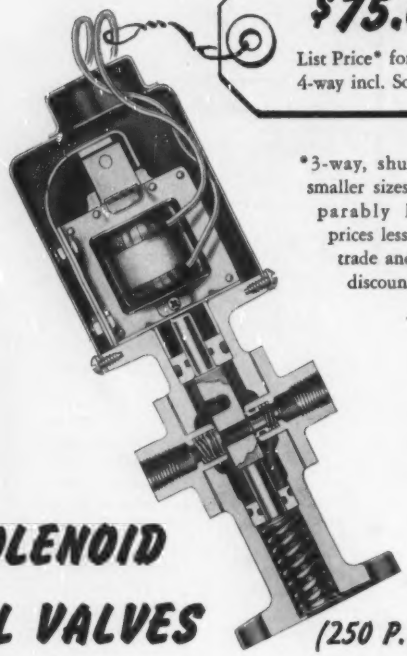

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NOTEWORTHY

Patents

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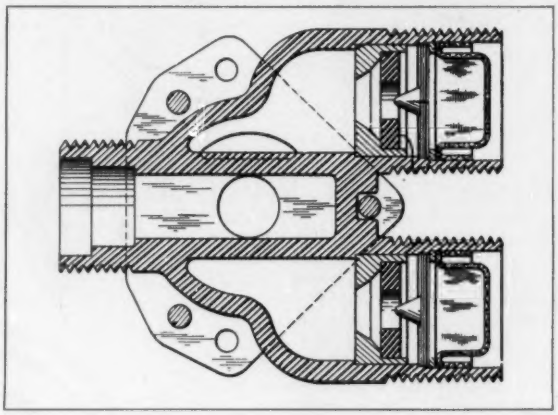
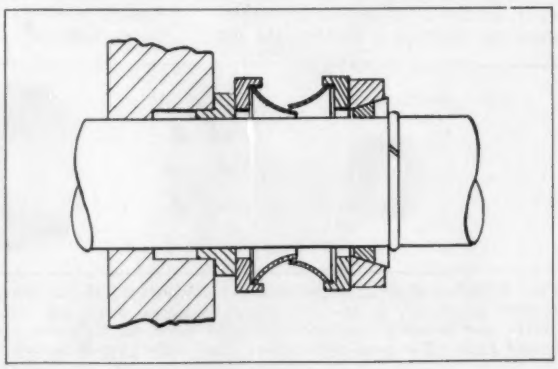
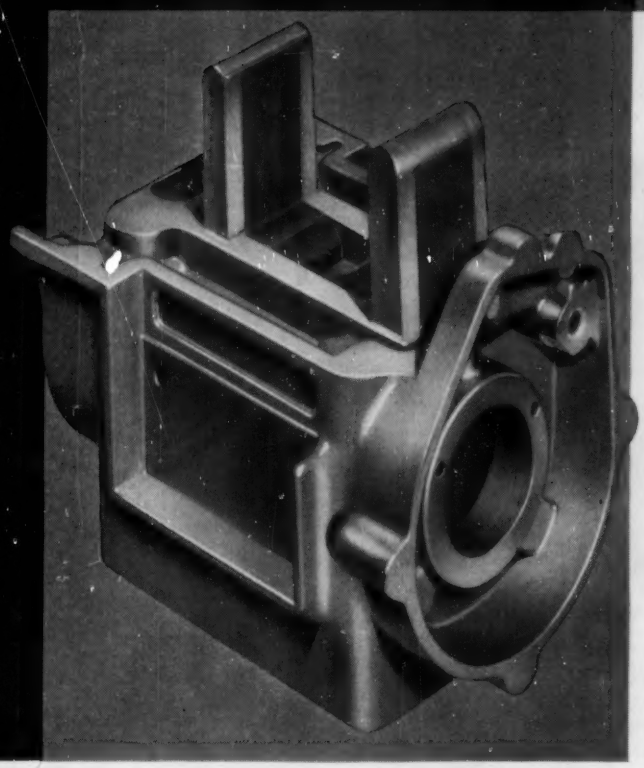


water inlet ports (upper and lower right), deform to restrict inlet flow volumes when either hot or cold-water supply pressures increase. Reductions in supply pressures, conversely, result in increased inlet-flow volumes. With changes in either hot or cold inlet-water temperatures, bimetal-actuated conical valve plungers move toward or away from their respective seats, restoring the mixed-fluid temperature to preset value. *Patent 2,772,833 assigned to Dole Valve Co. by Thomas B. Chace.*

Mechanical Seal

Telescoping metallic bell-shaped members maintain effective sealing contact pressures in a rotating-shaft fluid seal designed for use at high temperatures. Rotating seal elements abut split-ring retaining





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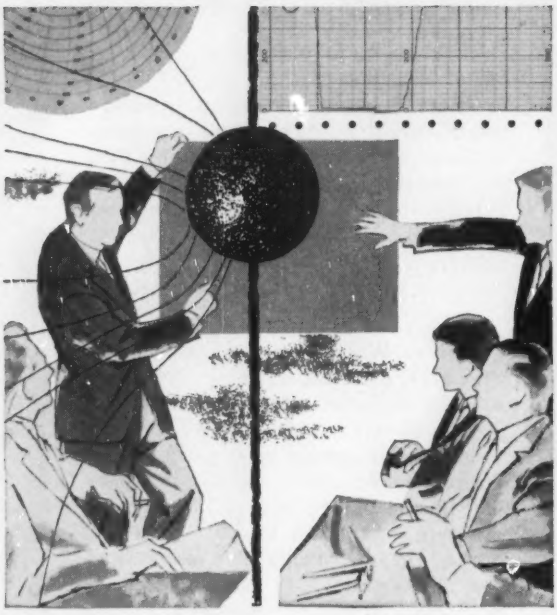

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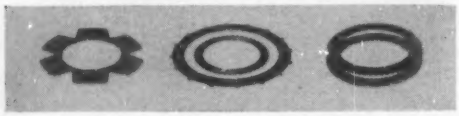

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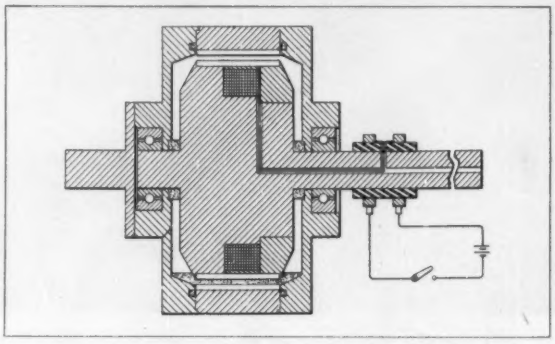
Noteworthy Patents

member that is fixed to the rotating shaft (right). Intermediate seal members, including the flexible telescoping bells, are driven at approximately one-half shaft speed by frictional engagement with high-speed rotating members. Principal sealing surface is between an abutment ring fixed in the stationary housing (left) and the left-hand tension-bell retaining ring. *Patent* 2,743,948 *assigned to Metal Seal & Products Inc. by August H. Heinrich.*

Magnetic-Fluid Clutch

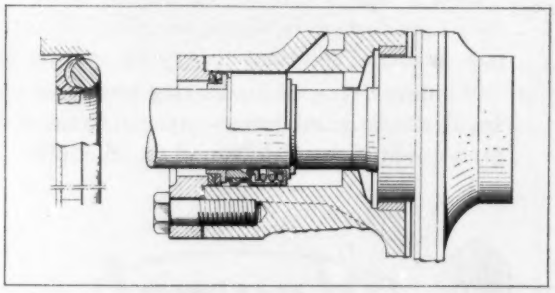
Ribs of nonmagnetic metal mounted on driving and driven clutch-member surfaces reduce slippage between the magnetized fluid and the clutch faces in a



high-torque magnetic-fluid clutch. Under slip conditions (magnetic field off), ribs mix the fluid and prevent creation of an overheated layer at the driving surfaces. Thermal breakdown or degeneration of the magnetic fluid is therefore minimized. Rib stirring action also reduces tendency of fluid particles to centrifuge or settle out. *Patent* 2,734,603 *assigned to General Electric Co. by Kenneth E. Wakefield.*

Seal Vibration Ring

Component separation and leakage in mechanical seals, induced by shaft whipping or misalignment, is prevented by a two-part Teflon vibration ring. Mount-



ed coaxially with the shaft and abutting the mechanical seal, the ring members (detail left) nest in an axial direction, compensating for and absorbing any tendency of the seal components to separate. Ring material is not affected by the deteriorating action of acids, gases, or aromatic fluids. *Patent* 2,760,794 *assigned to Garlock Packing Co. by William Hartranft.*

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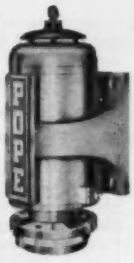

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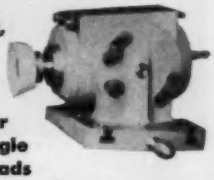

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SEALOL
THE BALANCED PRESSURE SEAL

Circle 551 on page 19

ELCO SCREWS

. . . Ask a man who has used them

Elco Screws are Good Screws

PIPE PLUGS These vital items are produced economically and accurately at ELCO by the cold-heading roll-threading method. The leak-proof "Dry-Seal" design is an ELCO specialty. Modified designs are engineered and produced to order. Second operation work is available, such as vent holes, safety wire holes, etc. ELCO Pipe Plugs are stocked in steel, stainless steel, aluminum, bronze, and brass. *Write for our stock list.*

WOOD SCREWS	PIPE PLUGS
MACHINE SCREWS	STOVE BOLTS
MACHINE SCREW NUTS	CAP SCREWS
TAPPING SCREWS	LAG SCREWS
THREAD-CUTTING SCREWS	DRIVE SCREWS
PHILLIPS AND SEMS SCREWS	SPECIAL SCREWS

COLD HEADED PRODUCTS

WE ALSO SPECIALIZE IN MAKING ANY OF OUR PRODUCTS OF THE FOLLOWING MATERIALS

Stainless Steel	Copper	Monel
Bronze	Silicon Bronze	Aluminum
Brass	Ambrac	Special Analysis

ELCO TOOL AND SCREW CORPORATION
1950 BROADWAY • ROCKFORD, ILLINOIS

Circle 552 on page 19

Efficient engineering and drafting departments use VEMCO drafting machines

because of such features as these:

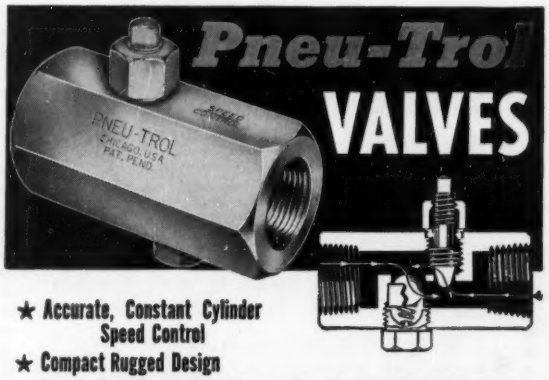
Automatic indexing for rapid settings.
Resilient scale chucks to insure firm grip.
Flexible, for speedy free movement.
VEMCO Versatilt provides easy floating motion on tilted boards.

VEMCO

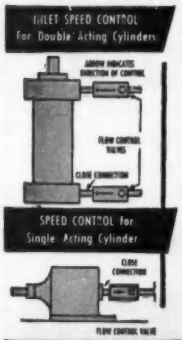
See your VEMCO dealer or write:

V. & E. Manufacturing Co.
Department AM-2
P.O. BOX 950-M • PASADENA, CALIFORNIA

Circle 553 on page 19



★ Accurate, Constant Cylinder Speed Control
★ Compact Rugged Design
★ Simple, Easy Speed Selection ★ For Air, Oil or Water Applications



Pneu-Trol Speed Control Valves, are widely used in hundreds of control applications because they combine in a short, compact body, a tapered fine thread needle for extremely accurate air or oil flow control and a floating retro ball check, which permits full flow in the opposite direction. Retro ball floats in most sensitive position to its seat, requiring only a slight differential pressure to fully open or close it.

Needle design permits maximum flow capacity in the controlled direction. Metal to metal needle and ball seats insure long trouble-free service. Simple, practical "O" gland structure eliminates troublesome leaking. Valve bodies machined from hex brass or aluminum for 2000 psi working pressures; steel and stainless steel for 5000 psi. Made in 5 female pipe sizes—⅛" to ¾". ATTRACTIVE PRICES . . . IMMEDIATE DELIVERY.

Write for illustrated circular and prices.

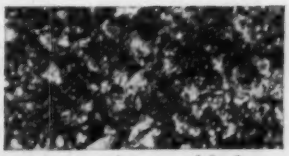
Pneu-Trol DEVICES, INC.
1336 N. KEATING AVENUE • CHICAGO 51, ILL

Circle 554 on page 19

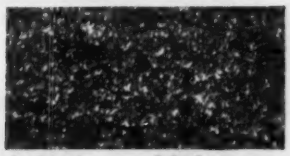
problem: *who makes long-lasting rubber O-rings of ±.002" tolerance at low cost?*

answer: *minnesota rubber and gasket company*

evidence:



compression molded



injection molded

Minnesota Rubber O-rings are injection molded by the exclusive Minnesota Rubber process. Result is increased resistance to abrasions and chemical actions due to consistent, unequalled high density. Evidence of the greater density of injection molding is shown here in cross sections of Standard Buna N compound, .026" x .019", magnified 240 diameters by University of Minn.

In addition, Minnesota Rubber's O-rings have no flash. Tolerances can be kept within ±.002 inch. Cost? M.R. O-rings cost as little as ordinary O-rings! And M.R.'s 100% inspection and quality control save you additional money in replacement costs, too.

free samples and data:

Free samples of Minnesota Rubber O-rings are available together with technical information and installation data.

minnesota rubber and gasket company

Originators of modern rubber injection molding

Dept. 806, 3630 Wooddale Ave., Minneapolis 16, Minn., WEst 9-6781

Circle 555 on page 19

No. 103-3502-1331

OIL TIGHT DUST TIGHT OMNIDIRECTIONAL

Exceptionally Rugged!

New

OIL TIGHT INDICATOR LIGHTS

for heavy duty use in industrial applications

Perfect oil-tightness is effected by retained oil-proof gaskets and the gasketed glass lens assembly . . . Install easily in a single 1" or 1-3/16" panel mounting hole. Also available for 11/16" mounting hole.

No. 103-3502-1211

No. 104-3502-XF10-231

Illustrations are approx. 70% actual size

DIALCO

A choice of *3 lens styles, 7 lens colors,* and other optional features provide adaptability.

DISCS with legends, behind flat lenses, deliver specific messages.

OIL TIGHT INDICATOR LIGHTS

accommodate a wide range of Incandescent and Neon Glow Lamps. For neon, DIALCO offers an exclusive feature — *BUILT-IN RESISTORS* (U. S. Patent No. 2,421,321) for operation on 105-125 V, or 210-250 V. Simple external resistors are provided for all higher voltages. *EVERY ASSEMBLY IS AVAILABLE COMPLETE WITH LAMP.* For design purposes we will gladly send you:

SAMPLES ON REQUEST—AT ONCE—NO CHARGE

***CATALOG "L-200"* gives you complete specs on DIALCO'S Oil-Tight Indicator Lights. Also available—a file of Special Catalogs on DIALCO Pilot Lights covering every indication requirement for automation and miniaturization.**

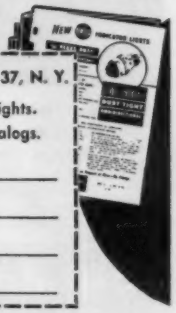
FREE— Brochure on "Selection and Application of Pilot Lights."

Foremost Manufacturer of Pilot Lights

DIALIGHT CORPORATION

54 STEWART AVE., BROOKLYN 37, N. Y.

HYACINTH 7-7600



DIALIGHT CORP., 54 Stewart Ave., Brooklyn 37, N. Y.

☐ Please send Cat. "L-200" on Oil-Tight Lights.

☐ "Selection" Brochure. ☐ Pilot Light Catalogs.

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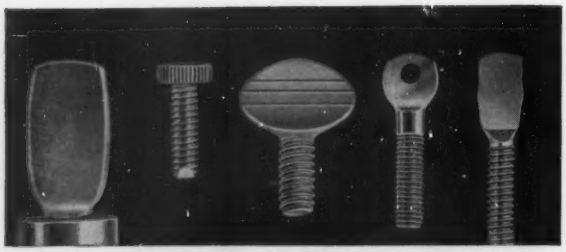
Company_____

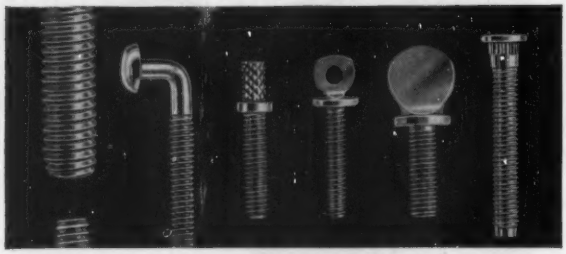
Address_____

City_____ State_____

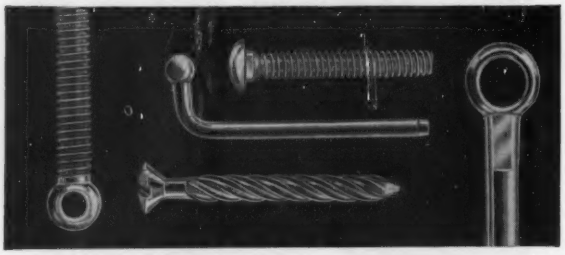
Circle 556 on page 19



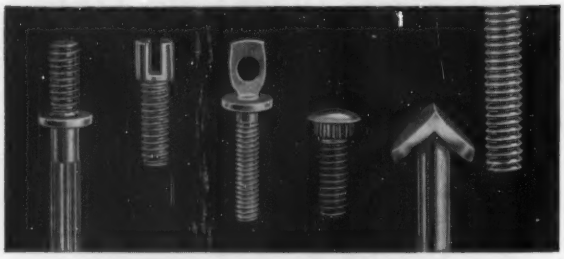
YOU CAN'T BEAT COLD FORMING



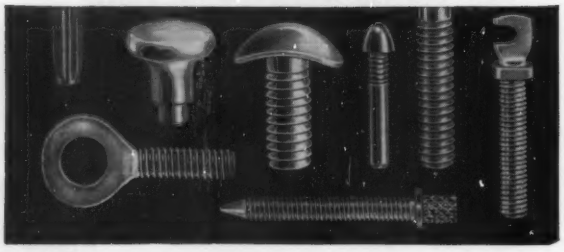
FOR PARTS LIKE THESE—AND



YOU CAN'T BEAT PROGRESSIVE



FOR COLD FORMING . . .



Machine screws and special fasteners are our business . . .
including square and hexagon machine screw nuts, Sems fasteners,
slotted tapping screws and Phillips Head Screws

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Division of The Torrington Company
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Your Template Supply House
"Quality At The Right Price"
IMMEDIATE DELIVERY ON DRAFTING TEMPLATES OF ALL TYPES
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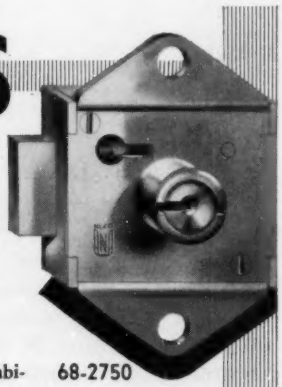
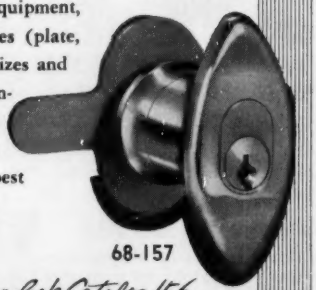
Circle 558 on page 19

LOCKS by National Lock



For a wide variety of metal products, including lockers, cabinets, control boxes, office equipment, etc. Selection of lock types (plate, lever and pin tumbler), sizes and finishes. Let our sales engineers work with you in recommending the lock (standard or special) to best meet your requirements.

68-2750



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Write for Lock Catalog 156

NATIONAL LOCK COMPANY
Rockford, Illinois

Circle 557 on page 19

Circle 559 on page 19

High-Impact-Strength High Temperature

BRUSH HOLDERS

New PHOENIX "Pemester"

High performance Phoenix "Pemester" Brush Holders and Caps are for motors that get the really rugged duty... new "Pemester" material gives high-impact-strength, dimensional stability up to 400°F. and molds to close tolerances in any quantity... Available *only* from Phoenix in the complete "Customized-Standard" line of sizes and types—or to your specifications.

Write for full information contained in big, new, easy-to-use Phoenix Catalog 57-L. Your copy free on request.

PHOENIX ELECTRIC MANUFACTURING CO.

4211 West Lake Street — Chicago 24, Illinois

Circle 560 on page 19

No stocks! All Abart Gears—spur, spiral, bevel, helical, internal, worm, rack, sprocket—are specially and precisely cut to your specifications. Any material—any quantity—96 pitch to 5/7 D.P.—¼" P.D. to 18" P.D. Send B/P and specs or sample for estimate. Request data-packed handbook.

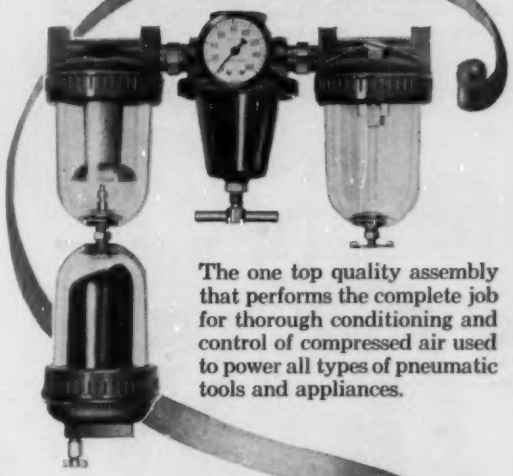
ABART GEAR and MACHINE CO.

4821 WEST 16th STREET — CHICAGO 50, ILLINOIS

Circle 561 on page 19

ARROW

AUTOPNEUMATIC CONTROL



The one top quality assembly that performs the complete job for thorough conditioning and control of compressed air used to power all types of pneumatic tools and appliances.

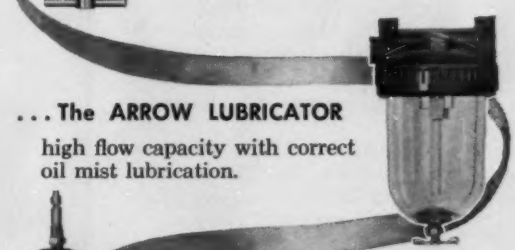
The AUTOPNEUMATIC CONTROL ASSEMBLY features . . .

. . . The ARROW FILTER

high flow capacity with filtration as required and low pressure drop.

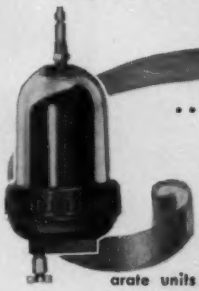
. . . The ARROW REGULATOR

high flow capacity with positive pressure control.



. . . The ARROW LUBRICATOR

high flow capacity with correct oil mist lubrication.



. . . The ARROW AQUAMATIC DRAIN TRAP

automatically disposes of collected moisture from filter with no loss of compressed air.

Assemblies and separate units supplied in pipe line sizes from ¼" NPT through 2" NPT.

QUALITY PRODUCTS SINCE 1914

Catalog and engineering data on request.

ARROW TOOLS, INC.

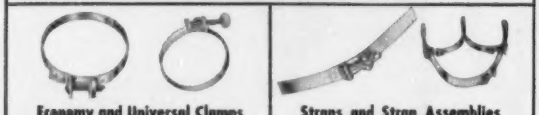
1918 S. KOSTNER AVE. • CHICAGO 23, ILL.

Circle 562 on page 19

Marman Clamps, Straps, Couplings,

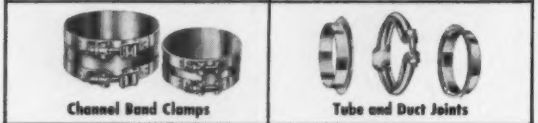
SIMPLIFY FASTENING AND JOINING PROBLEMS

If you are concerned with assembly of components, connection of tubing and ducting, or support of ducts and accessories, Marman Products can help solve design problems. Marman offers a wide range of clamps, straps and couplings in standard sizes or to your specifications. Write today for full catalog information, or engineering assistance.



Economy and Universal Clamps | Straps and Strap Assemblies

Flexible Couplings | V-Band Couplings



Channel Band Clamps | Tube and Duct Joints

MARMAN DIVISION
Aeroquip Corporation

11214 EXPOSITION BLVD., LOS ANGELES, CALIFORNIA
IN CANADA: AEROQUIP (CANADA) LTD., TORONTO 10, ONTARIO

Circle 563 on page 19

1001 USES FOR HARDWARE

Whether you make tool boxes or locomotives, Stanley's Industrial Hardware Department is set up solely for your benefit.

Thousands of original equipment manufacturers already call on our unequalled design and production facilities to help make their products function more efficiently.

Let Stanley help you. Send for our industrial brochure, "At Your Service." Stanley Hardware, Division of The Stanley Works, 692 Lake St., New Britain, Conn.

STANLEY

again available

"EVALUATING ENGINEERS"

by Randolph W. Chaffee

. . . to recognize talent and reward achievement

How evaluation yardsticks are established
Appraising creative engineering requirements
Ranking engineering jobs
Summary of job values
Classification listing of job requirements and related typical positions
Allocation of positions to grades
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A brilliant discussion of methods for job evaluation and merit rating in creative engineering by one of the country's outstanding authorities in this field. Use the order form below and get your copies while the supply lasts. Remittance with your order will greatly facilitate handling.

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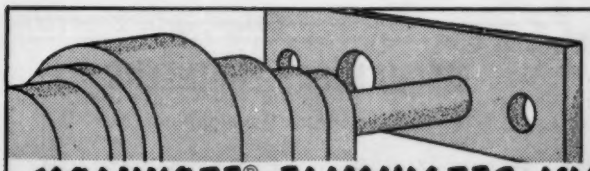


MOLYKOTE® ELIMINATES JUMPY 'STICK-SLIP' ON HEAVY GRINDER . . . AN IMPOSSIBLE JOB WITH OILS AND GREASES

Here's the way this report came to us:

"On a heavy cylindrical grinder, the grinding head which weighed 8,000 pounds had to be moved hydraulically at feed rates of .00025" per second. It turned out to be an impossible job with oils and greases. Finally, we cleaned the ways with benzine and rubbed in MOLYKOTE, Type Z powder. It sure was a relief to see the grinding head move without the previous jumpy, stick-slip behavior."

Impressive story? Yes, it is . . . but there are thousands like it from industrial concerns the world over. In their own words they tell us how design problems on low speed mechanisms at extreme pressure are solved by MOLYKOTE Lubricants.

More interesting reports from satisfied users of MOLYKOTE LUBRICANTS . . .

- . . . prolonged life of bronze Oilite connecting rod bushings 5 times on pneumatic sander. (Field Report 24-47)
- . . . dropped the temperature of rubber rolling mill bearings from 160°F to 95°F.
- . . . reduced friction 30% on rubber "O" rings, packings and seals.
- . . . multipled number of operating cycles in valve test 5 times.
- . . . reduced by 50% the power needed to move supports on ways and guides. (Field Report 24-31)
- . . . reduced load 25% in coining operation of plastics manufacturer. (Field Report 18)

753

The ALPHA MOLYKOTE Corporation

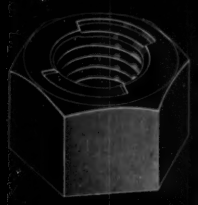
Main Factories: 65 Harvard Avenue, Stamford, Conn.
71 Arnulfstrasse, Munich 19, Germany

Circle 565 on page 19

LESS torque-scatter WITH THE

M·F

Uni-Torque® LOCK NUT



(Production men, of course, know that a lock nut with a "scatter-pattern" interrupts production and increases rejects.)

. . . and constant-torque M-F costs NO MORE!

Why do designers want a lock nut that shows an even pattern of torque, nut after nut, keg after keg?

Because it means uniform bolt tension, which is important in keeping the finished product true to original design.

NOW TRY THE M.F TWO-WAY LOCK NUT!

DOUBLE CHAMFERED — May be automated without selective devices. Starts from either end—locks in body of nut, not at the crown. Write for specifications.

MAC LEAN-FOGG Lock Nut Company

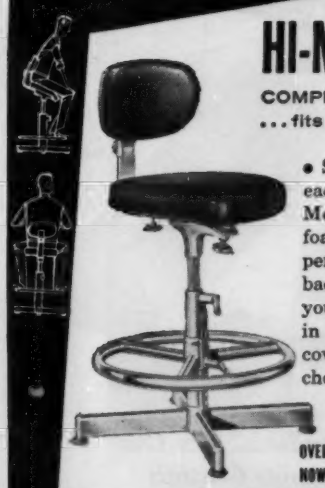
5535 N. Wolcott Street
Chicago 40, Illinois

Circle 566 on page 19

IF YOU SIT HIGH, YOU'LL "SIT HANDSOME" IN A Cramer

HI-MODEL CHAIR

COMPLETELY ADJUSTABLE
. . . fits YOUR build just right



• Scientifically planned in each detail, the Cramer Hi-Model has thick shaped-foam cushions and independently-adjustable seat, back and footring to support you comfortably and aid you in your work. Removable covers available in a wide choice of colors and fabrics.

OVER 100,000 CRAMER HI-MODEL CHAIRS NOW IN USE ALL AROUND THE WORLD!

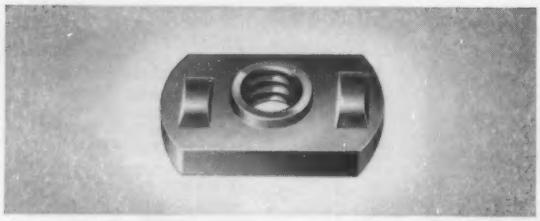
Cramer Hi-Model 4D-22T, pictured, with forward-tilt seat; others available, all low-gravity balanced for use ON CASTERS if desired.

LIKE MORE INFORMATION?

Cramer Posture Chair Co. Inc., MD-27
1205 Charlotte, Kansas City 6, Mo.
Please send complete facts on Cramer Hi-Model chairs for working architects and engineers.

Name_____
Firm_____
Address_____

Circle 567 on page 19



Patent Applied for

THE NEW OHIO "RN" WELD NUT

This nut, which is applied by resistance welding, becomes the PRIMARY FASTENER in fastener assemblies. It offers these distinctive advantages:

- **SIMPLIFIED PRODUCT DESIGN**
- **LIGHTNING-FAST APPLICATION**
  (By resistance welding)
- **PRIMARY FASTENER PERMANENTLY POSITIONED**
  (No retapping required)
- **SPLIT-SECOND ASSEMBLY OF PRODUCT COMPONENTS**
  (Made possible by pre-attached primary fastener)
- **SHIPMENT FROM STOCK**

Samples and information furnished upon request.

OHIO WELD FASTENERS
THE PRIMARY FASTENER IN FASTENER ASSEMBLIES

THE OHIO NUT & BOLT CO. • 33 FIRST AVE., BEREA, O.

Circle 568 on page 19

MECHANICAL ENGINEERS

Research and Development

Interesting positions open for mechanical engineers on a wide variety of projects in the following fields:

- **Mechanism Analysis**
- **Machine Design**
- **Servomechanisms**
- **Experimental Stress Analysis**
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B.S. to Ph.D. in mechanical engineering with 3 to 5 years' experience in one of these fields essential. These are permanent positions offering an opportunity to use your initiative and creative ability. We offer excellent employee benefits including tuition free graduate study. For employment application, call Calumet 5-9600, or write

Mr. J. A. Metzger

ARMOUR RESEARCH FOUNDATION
of
Illinois Institute of Technology
10 West 35th Street
Chicago, Illinois

Circle 569 on page 19

ARENS... *Dependable, Low Cost Remote Controls*

Write for Catalog

40 page Push-Pull Control Catalog. Write for it.

The Heil Co., leading manufacturer of truck bodies, relies on Arens 6-D Heavy Duty Remote Push-Pull Controls to actuate hoist mechanisms. For your remote control application, consider an Arens Control in your design planning. Arens low cost standard controls can give you the benefit of quantity production. We also engineer "specials."

ARENS CONTROLS, INC.
2009 Greenleaf Street • Evanston, Illinois

ENGINEERS

AVAILABLE OR WANTED

AVAILABLE: Graduate M.E. seeking sales line from well established company. Can do own estimating and presentation work. Northern Ohio. Address Box 912, MACHINE DESIGN, Penton Bldg., Cleveland 13, Ohio.

WANTED: Engineers, mechanical and electrical, for design and development of machine tools. Hydraulics, electronics, and servo-mechanisms. Inquiries held confidential. The Monarch Machine Tool Company, Sidney, Ohio.

WANTED: Chief Draftsman (Richmond, Virginia)—Rapidly growing industry requires services of a Chief Draftsman with five to ten years experience in sheet metal design—drafting, with three to five years experience in a supervisory capacity. The applicant should have a general knowledge of part numbering systems, filing systems, and a specific knowledge of drafting procedures as applied to the development in the flat of sheet metal shapes. He should also be familiar with manufacturing processes such as spot welding, arc welding, forming, bending, shearing, penciling, matching, painting and preparation for painting, and general assembly line work, and have a specific understanding of tools and dies. The position carries excellent salary remuneration with all company benefits. Please send complete resume, stating salary requirements, to: Chief Draftsman, Post Office Box One, Richmond, Virginia.

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Abart Gear and Machine Co. 241
Acadia Synthetic Products, Division of Western Felt Works 143
Acushnet Process Co. 184
Aeroquip Corporation, Marman Division 242
Airborne Accessories Corporation 34
Allen-Bradley Co. 37, 38
Allen Manufacturing Co. 199
Alpha Molykote Corporation, The 243
Alvin & Co., Inc. 240
American Brakeblok Division, American Brake Shoe Co. 234
American Brake Shoe Co., American Brakeblok Division 234
American Brass Co., The 16
American Machine and Metals, Inc., United States Gauge Division 170
American Smelting and Refining Co., Federated Metals Division 157
American Steel & Wire Division, United States Steel Corporation 66, 67, 189
Ampco Metal, Inc. 248
Arens Controls, Inc. 244
Armour Research Foundation of Illinois Institute of Technology 244
Armstrong Cork Co., Industrial Division 158, 159
Arrow Tools, Inc. 241
Autron Engineering, Inc. 208
Aviation Developments, Inc. 164

Babcock & Wilcox Co., The, Tubular Products Division 83
Barksdale Valves 232
Bethlehem Steel Co. 209
Bodine Electric Co. 1
Boston Gear Works 221
Bruning, Charles, Co., Inc. 48, 49

Cambridge Wire Cloth Co., The 216
Carpenter Steel Co., The 51
Cartriseal Corporation 175
Century Electric Co. 82
Chicago Molded Products Corporation 139
Chicago Rawhide Manufacturing Co. 2
Chrysler Corporation, Industrial Engine Division 204
Cincinnati Gear Co., The 24
Clearprint Paper Co. 61
Cleveland Cap Screw Co., The 174
Climax Molybdenum Co. 179
Columbia-Geneva Steel Division, United States Steel Corporation 58, 59, 66, 67, 189
Columbia Steel & Shafting Co., Summerill Tubing Division 74
Cone-Drive Gears Division, Michigan Tool Co. 156
Copperweld Steel Co., Steel Division 23
Corning Glass Works 193
Cornish Wire Co., Inc. 40
Cramer Posture Chair Co., Inc. 243
Crane Packing Co. 212
Crocker-Wheeler Division, Elliott Co. 171
Crucible Steel Company of America 63

Dayton Rubber Co., The, Industrial O.E.M. Division 182, 183
De Laval Steam Turbine Co. 163
Dialight Corporation 239
Diamond Chain Co., Inc. 227
Dodge Manufacturing Corporation 30, 31
du Pont, E. I. de Nemours & Co., Inc. 75
Durakool, Inc. 220
Dynamatic Division, Eaton Manufacturing Co. 161

Eastman Manufacturing Co. 64
Eaton Manufacturing Co., Dynamatic Division 161
Elastic Stop Nut Corporation of America 32
Elco Tool and Screw Corporation 238
Electro Dynamic Division of General Dynamics Corporation 203
Elliott Co., Crocker-Wheeler Division 171
Erie Bolt & Nut Co. 236
Exact Weight Scale Co., The 218

Fairbanks, Morse & Co. 60
Fastex Division, Illinois Tool Works 27
Federal-Mogul-Bower Bearings, Inc., Federal-Mogul Division 29
Federal-Mogul Division, Federal-Mogul-Bower Bearings, Inc. 29
Flexible Tubing Corporation 205
Foote Bros. Gear and Machine Corporation 33
Formica Corporation 80, 81

Gardner-Denver Co. 186
Gast Manufacturing Corporation 195
Gates Rubber Co., The 180
General Aniline & Film Corporation, Ozalid Division 36
General Dynamics Corporation, Electro Dynamic Division 203
General Electric Co. 206, 207, 236
Gerotor May Corporation 172
Gleason Works 9
Gray Iron Founders' Society, Inc. 167

Hansen Manufacturing Co., The 178
Haynes Stellite Co., A Division of Union Carbide and Carbon Corporation 46
Heinze Electric Co. 28
Hilliard Corporation, The 192
Hoover Ball and Bearing Co. 55
Hubbell, Harvey, Inc. 188
Hunter Douglas Aluminum Corporation 151
Hyatt Bearings Division of General Motors Corporation 196, 197

Illinois Tool Works, Fastex Division 27
Industrial Timer Corporation 166
Inland Steel Co. 25
International Business Machines Corporation 176, 177
International Nickel Co., Inc., The 78

Johnson, Carlyle, Machine Co., The 165
Jones & Laughlin Steel Corporation 217

Kaydon Engineering Corporation, The 21
Koppers Company, Inc., Chemical Division 65

La Salle Steel Co. 7
Lehigh Chemical Co. 26
Lincoln Electric Co., The 149
Link-Belt Co. 79
Lockheed Aircraft Corporation 219
Logansport Machine Co., Inc. 72, 73
Lord Manufacturing Co. 70

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Advertising Index

Lovejoy Flexible Coupling Co. 200
Lukens Steel Co. 71

McGill Manufacturing Co., Inc. 141

MacLean-Fogg Lock Nut Co. 243
Madison-Kipp Corporation 54
Mahon, R. C., Co., The 88
Marman Division, Aeroquip Corporation 242
Master Electric Co., The ..... Inside Back Cover
Michigan Tool Co., Cone-Drive Gears Division 156
Minnesota Mining and Manufacturing Co., Adhesives and Coatings Division 39
Minnesota Rubber and Gasket Co. 239
Miniature Precision Bearings, Inc. 16-A
Mt. Vernon Die Casting Corporation 62
Muskegon Piston Ring Co., Rotary Seal Division 16-B

National Acme Co., The 35
National Lock Co. 240
National Lock Washer Co., The 4
National Tube Division, United States Steel Corporation 189
National Vulcanized Fibre Co. 44
New Departure, Division of General Motors Corporation 11
New Hampshire Ball Bearings, Inc. 231
Norgren, C. A., Co. 45
Norma-Hoffmann Bearings Corporation ..... Inside Front Cover
Norton Co. 15
Nosco Plastics, Inc. 229
Numatics, Inc. 215

Ohio Gear Co., The 214
Ohio Nut & Bolt Co., The 244
Ohmite Manufacturing Co. 85
Orange Roller Bearing Co., Inc. 201
Ozalid, A Division of General Aniline & Film Corporation 36

Palnut Co., The 160
Parker Appliance Co., The, Tube & Hose Fittings Division 77
Parker Rust Proof Co. 225
Phoenix Electric Manufacturing Co. 241
Pneu-Trol Devices, Inc. 238
Pope Machinery Corporation 235
Potter & Brumfield, Inc. 147
Progressive Manufacturing Co., The, Division of The Torrington Co. 240

Racine Hydraulics & Machinery, Inc. 50
Reeves Pulley Co., Division of Reliance Electric and Engineering Co. 187
Reliance Electric and Engineering Co., Reeves Pulley Division 187
Resistoflex Corporation 143
Robbins & Myers, Inc. 168, 169
Rockwood Sprinkler Co. 247
Roper, Geo. D., Corporation 162
Rotary Seal Division, Muskegon Piston Ring Co. 16-B
Roth Rubber Co. 84
Ruthman Machinery Co., The 190

Saginaw Steering Gear Division, General Motors Corporation 191
Sealol Corporation 237
Sharon Steel Corporation 153
Shell Oil Co. 41
SKF Industries, Inc. 185
Southwest Products Co. 237
Square D Co. 52, 53
Standard Pressed Steel Co., Flexloc Locknut Division 194
Stanley Works, The Hardware Division 242
Stearns Electric Corporation 198
Stewart-Warner Corporation, Die Casting Division 233
Summerill Tubing Division, Columbia Steel & Shafting Co. 74

Tennessee Coal & Iron Division, United States Steel Corporation 58, 59, 66, 67, 189
Timken Roller Bearing Co., The ..... Back Cover
Torrington Co., The 13
Torrington Co., The, The Progressive Manufacturing Co. Division 240

Union Carbide and Carbon Corporation, Haynes Stellite Co. 46
United-Car Fastener Corporation 173
United States Gauge, Division of American Machine and Metals, Inc. 170
United States Graphite Co., Division of The Wickes Corporation 42, 43
United States Steel Corporation, Subsidiaries 58, 59, 66, 67, 189
United States Steel Export Co. 58, 59, 66, 67, 189
United States Steel Supply Division, United States Steel Corporation 58, 59, 189

Vacuum Metals Corporation, Division of Crucible Steel Company of America 213
Valley Electric Corporation 190
Valvair Corporation 155
V. & E. Manufacturing Co. 238
Veeder-Root, Inc. 202
Vickers Electric Division, Vickers, Inc., A Unit of Sperry Rand Corporation 47
Vickers, Inc., Division of Sperry Rand Corporation 76
Victor Manufacturing & Gasket Co. 69

Wagner Electric Corporation 68
Warner Electric Brake & Clutch Co. 86, 87
Webster Electric 57
Western Felt Works, Acadia Synthetic Products Division 145
Westinghouse Electric Corporation 181
Wickes Corporation, The, The United States Graphite Co. Division 42, 43
Wiegand, Edwin L., Co. 200
Winsmith, Inc. 210
Worthington Corporation 223

Engineers Available or Wanted 244

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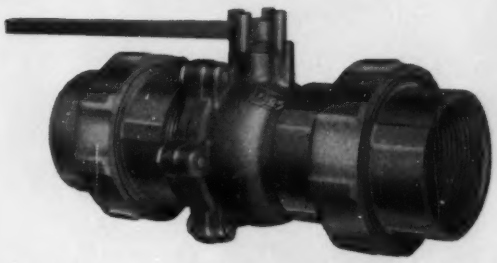

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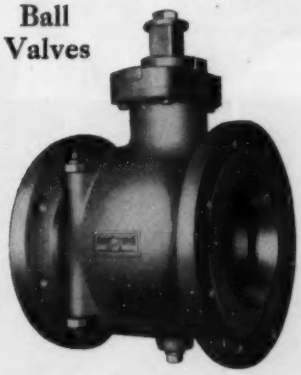

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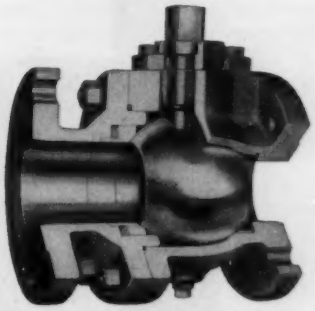

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Circle 571 on page 19

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D-83

Write for Bulletin 33.

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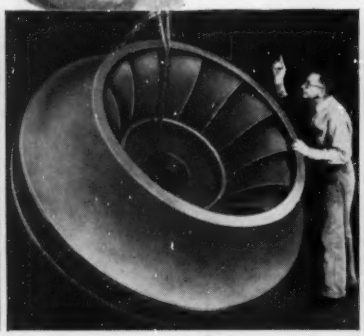

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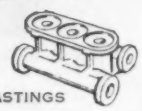

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SHELL-MOLDED CASTINGS

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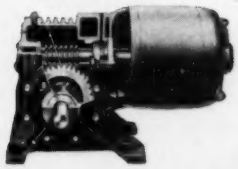

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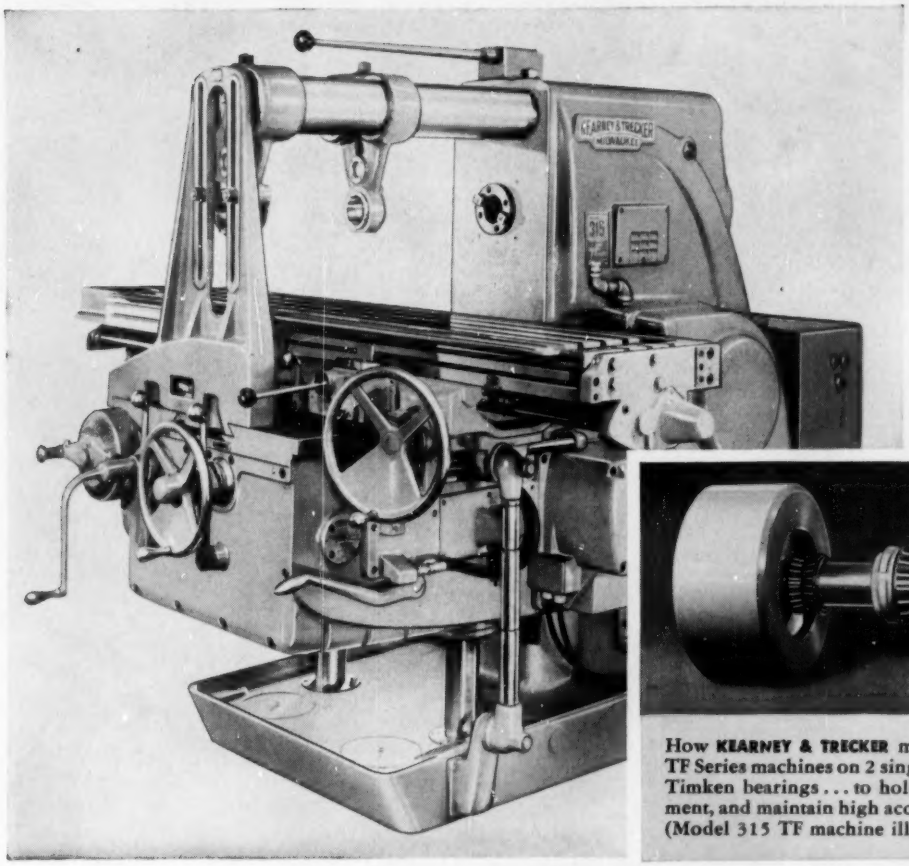
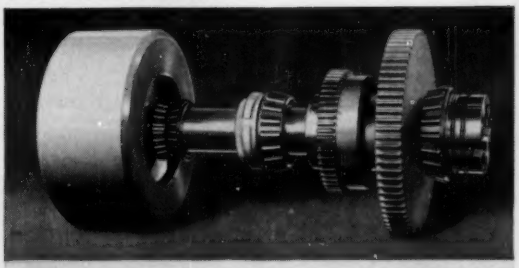
MASTER ELECTRIC MOTORS

THE MASTER ELECTRIC COMPANY • Dayton 1, Ohio

Circle 402 on page 79





How **KEARNEY & TRECKER** mounts the spindle of its TF Series machines on 2 single-row and 1 double-row Timken bearings . . . to hold spindle in rigid alignment, and maintain high accuracy through 24 speeds. (Model 315 TF machine illustrated).

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This symbol on a product means its bearings are the best.

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Circle 403 on page 19